RADIAN/95/0130

FINAL SCIENTIFIC AND TECHNICAL REPORT

FUTURE ARMORED RESUPPLY VEHICLE (FARV)

CONCEPTUAL FUEL SYSTEM DESIGN

1 MARCH 1995

**PREPARED FOR: U.S. ARMY MOBILITY
TECHNOLOGY CENTER - BELVOIR
CONTRACT NUMBER DAAK70-92-D-0004
TASK ORDER 0130, CDRL A084**

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This document presents an idealized automated fuel system applicable to unique requirements. The system accepts fuel at high rates, transports fuel in a battlefield environment, and supplies fuel to a vehicle equipped to receive it without exposing the crew to small arms fire. The fuel system design incorporates controls and mechanisms which compensate for battle damage and irregularities found in previous fuel systems for tracked vehicles. The fuel system is a functional part of a ReArm/Resupply system which also handles munitions and liquid propellant, automatically.

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ACRONYMS AND ABBREVIATIONS

@	at
/	per
°	Degree
%	Percent
ac/AC	alternating current
A/D	Analog to Digital
AFAS	Advanced Field Artillery System
AMC	Army Material Command
AMC-R	Army Material Command Regulation
amps	ampere
ANSI	American National Standards Institute
APS	Auxiliary Power System
ASM	Armored Systems Modernization
BDAR	Battle Damage Assessment and Repair
BRDEC	Belvior Research, Development and Engineering Center
C	centigrade
C3	Command, Communication, and Control
cm/CM	centimeters
CMOS	Complimentary metal oxide semiconductor
COTS	Commercial-Off-The-Shelf
CPU	Central Processor Unit
dc/DC	Direct Current
dia	diameter
DID	Data Item Description
DS	Direct Support
EEIM	Electronic/Electrical Interface Module
EMI	Electro-Magnetic Interference
EMP	Electro-Magnetic Pulse
ETOA	Engineering Trade-Off Analysis
F	Fahrenheit
FARV	Future Armored Resupply Vehicle
FAS	Field Artillery Systems
FLOT	Forward Line of Own Troops
FMM	FARV Mission Module
FPS	Feet per second
FSM	Fuel Storage Module
ft	Feet
FTM	Fuel Transfer Module
G	Gravity
GFI	Government Furnished Information
gpm/GPM	Gallons Per Minute
GS	General Support
HDBK	Handbook
HFE	Human Factors Engineering
hp/HP	horsepower
hr	hour
Hz	Hertz
ID	Inside Diameter
ILS	Integrated Logistics Support
in.	inches
Kg	Kilogram
km	kilometer(s)
KPH	kilometers per hour

Lbs	Pounds
LCD	Liquid Crystal Display
LP	Liquid Propellant
lpm/LPM	liters per minute
LRP	Logistic Rearm Point
LRU	Line Replaceable Unit
mA	Milliamp
MAC	Maintenance Allocation Chart
max/MAX	maximum
mi	miles
MIL	Military
min	Minimum
mm	millimeters
MM	Mission Module
MMCS	Mission Management and Control System
MOPP	Mission Oriented Protective Posture
MOS	Military Occupational Specialty
MPa	Mega Pascals
mph	miles per hour
MPU	Main Propulsion Unit
MTBF	Mean Time Between Failure
mV	Millivolt
NBC	Nuclear, Biological, Chemical
NDI	Non-Developmental Item
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NPT	National Pipe Tap
OMS	Operational Mode Summary
ORD	Operational Requirements Document
OVE	Other Vehicular Equipment
PEO	Program Executive Office
PMCS	Preventive Maintenance Checks and Services
POL	Petroleum, Oil and Lubricant
PPM	Parts per million
psi/PSI	Pounds per Square Inch
psig/PSIG	Pounds per Square Inch, Gage
RAM	Reliability, Availability, Maintainability
RF	Radio Frequency
rpm/RPM	Revolutions Per Minute
SARS	Standard Army Refueling System
STD	Standard
TBD	To Be Determined
TTL	Transistor to transistor logic
V	Volt
vac/VAC	Volts, Alternating Current
VFM	Vehicle Fuel Module
vdc/VDC	Volts, Direct Current
W	Watt

SECTION ONE

INTRODUCTION

1.1 TASK OBJECTIVE

The objective of this effort is to analyze the Future Armored Resupply Vehicle (FARV) Conceptual Fuel System and evaluate the fuel transfer requirements as presented in the FARV Operational Requirements Document (ORD) and the Engineering Trade-Off Analysis (ETOA) Report. The evaluation and analysis results are to be presented as design requirements/parameters that reflect "lessons learned" and full mission capability. The resulting report shall identify problems associated with Refuel/Defuel and transfer rates, storage and internal transfer of fuel, and automation of sub-systems.

The recommended fuel system design shall:

- satisfy all ORD requirements relating to the transfer of fuel,
- incorporate and be compatible with Standard Army Refueling System (SARS) fuel componentry,
- identify components necessary for fuel receipt, storage, and transfer, and
- identify the system interface requirements and the impact on the munitions and liquid propellant (LP) transfer system.

The recommended design and narrative (report) shall reflect criteria established by MIL-STD-1472D, Human Engineering Design Criteria for Military Systems, Equipment and Facilities.

The narrative shall outline the efforts required to ensure the safety of the vehicle and its' crew as defined by MIL-STD-882C, System Safety Program Requirements.

Potential problems, or concerns, relating to Logistic Supportability shall be identified, including but not limited to:

- safety and health hazards experienced during the operation and/or repair of the system,
- training unique to the operation or maintenance of the system,
- skill levels required to operate and maintain the system, and

- levels at which repair of system modules and components would be accomplished.

1.2 OVERVIEW

The FARV and the Advanced Field Artillery System (AFAS) are companion tracked vehicles that are destined to replace the existing field artillery systems. The two vehicles represent the only developmental vehicle program that received continuing funding under the Army's Armored Systems Modernization (ASM) program. The AFAS and FARV have been realigned under the newly created Program Executive Office for Field Artillery Systems (PEO, FAS).

The FARV is an armored and tracked resupply vehicle that operates in support of elements near the Forward Line of Own Troops (FLOT). The FARV and AFAS are employed as "sets" in support of offensive and defensive operations.

The current self propelled artillery and support vehicles cannot maintain the speeds required by projected battle situations, have limited payload capacity and lack automation. The FARV will incorporate an automated Rearm/Resupply system which will transport and resupply the AFAS with munitions, LP and fuel on an "as-needed" basis; will be capable of rapid maneuvering and sustained speeds equal to Main Battle Tanks and calvary units (M1A2 and M2/M3); and will be capable of automated resupply with the crew remaining within the confines of the vehicle. The FARV will enable the AFAS to attain increased and sustained level of firepower in a wide range of climatic environments.

1.3 APPROACH

The general technical approach employed to prepare this report is as required by ANSI Z39.18, Scientific and Technical Reports - Organization, Preparation, and Production, as modified by DID-MISC-80711.

The objective of this effort was not to repeat analysis and evaluation that had been previously performed. Rather, the objective was to build upon information derived from previous studies and recommendations; conduct a market analysis to determine the availability of Commercial-Off-The-Shelf (COTS) and Non-Developmental Item (NDI) components; incorporate "lessons learned" and recommendations into a conceptual design; and define the required components and fabricated items in generic terms.

Data and requirements (specifications) upon which this report is based are derived from the following Government Furnished Information (GFI):

- Operational Requirements Document (ORD) for the Future Armored Resupply Vehicle (FARV)

- Future Armored Resupply Vehicle (FARV) Operational Mode Summary/Mission Profile
- System Performance Specification, Second Draft, Future Armored Resupply Vehicle (FARV)
- Final Report, Future Armored Resupply Vehicle (FARV) Refuel Transfer Technology
- Military Handbook, SARS Fuel System Design Guide for Military Refuelable Vehicles and Ground Equipment
- Engineering Trade-Off Analysis (ETOA) for the Future Armored Resupply Vehicle (FARV)
- AMC Regulation 70-17, Implementation of the Standard Army Refueling System (SARS)
- Conceptual definition of the "New Start Chassis" with FARV Mission Module (FMM)

SECTION TWO

FARV MISSION ANALYSIS

2.1 INTRODUCTION

The purpose of this section is to identify and consolidate the limiting parameters associated with fuel and Refuel/Defuel subsystems on the FARV. The source Documents include the 29 October, 1993, Final Report - Future Armored Resupply Vehicle (FARV) Refuel Transfer Technology; the 7 July, 1993, Second Draft - System Performance Specification, Future Armored Resupply Vehicle (FARV); the Advance Draft of Revision C to the SARS Fuel System Design Guide For Military Refuelable Vehicles and Ground Equipment; and the 20 July, 1989, AMC Regulation No. 70-17, "Implementation Of The Standard Army Refueling System".

2.2 MISSION OVERVIEW

The FARV is the companion vehicle to the AFAS. It provides automated resupply of ammunition and fuel to the AFAS under battlefield conditions and in adverse environmental conditions. The FARV enables the AFAS to achieve independent mission execution in all phases of fast moving battle situations while increasing survivability.

2.2.1 Employment/Deployment

The FARV and the AFAS will replace, on a one-for-one basis, the existing inventory of M109A6 (Paladin) track mounted, mobile, howitzers. While commonly employed in groups of two or more pairs, the set will be capable of singular action. When not resupplying the AFAS, the FARV will not be co-located with the AFAS, it will be located no more than 750 meters (2,460 feet (ft)) to the rear of the AFAS position. The FARV accompanies the AFAS when it displaces to provide fire support, or for survivability. After, and in conjunction with, each move, the FARV will dock with the AFAS for automated resupply of ammunition and/or fuel. Resupply of the AFAS under field or combat conditions is accomplished without crew dismount. The FARV will replenish its on-board stores at the field Logistics Rearm Point (LRP) as required.

2.2.2 Mission Profiles

The frequency of movement, travel distance, and number of resupply docking maneuvers for the AFAS and FARV will vary with the combat scenario, environment, terrain, and posture. The weighted arithmetic mean of the scenarios presented in the Operational Mode Summary (OMS) are as follows:

COMBAT ACTIVITY	AFAS	FARV
Fire Missions *	23	--
Rearm/Refuel	20.4	20.4
Upload at LRP	--	2.2
Moves, Tactical **	12	12
Moves, Survivability	20	22.6
Distance, kilometers (km) (miles (mi))	46.8 (29.1)	73 (45.4)

* The average mission fires 16 rounds
** Reflects support of maneuver elements over 26 km (16.2 mi)

These values reflect a single measure level of effort for a 24 hour (hr) period of combat.

2.3 OPERATIONAL REQUIREMENTS

Operational requirements for the FARV fuel and Refuel/Defuel subsystems are outlined below. The requirements are directly related to mission profiles identified in 2.2.2.

2.3.1 Elements of Refuel/Resupply and Fuel consumption in a 24 hour period.

- tactical assignment and combat survivability movement. The FARV accompanies the AFAS on all movements; this equates to an average of 20.4 survivability moves and 23 tactical moves over a 24 hour period. Each move requires the FARV to maneuver, dock and resupply the AFAS with ammunition and fuel as necessary.

- logistic stores replenishment movement. Upon transfer of the FARV basic load to the AFAS, the FARV travels to the LRP located, on the average, 2.5 km (1.6 mi) to the rear of the AFAS/FARV position. In a battlefield day, the FARV would average 2.2 refurbishment moves. At the LRP, 90 minutes is allowed for the upload of ammunition and fuel.

- when the Main Propulsion Unit (MPU) is not operating, the Auxiliary Power System (APS) supplies power adequate for systems operation; e.g., communication, subsystem monitoring, environmental control, refuel/defuel system operation.

- long distance moves. The AFAS and FARV, as a set, travel up to 465 km/day (289 mi/day) at speeds averaging 47 kilometers per hour (KPH) (29.2 miles per hour (MPH)) on dry, hard surfaced, roads. Resupply of fuel, during long distance moves, will be in accordance with SARS parameters (AMC Regulation 70-17, 20 July 1989).

2.2.3 Parameters governing the receipt of fuel for the AFAS and FARV.

- compatibility. The AFAS and FARV must be able to receive fuel from a FARV, an LRP, a Petroleum, Oils and Lubricants (POL) tanker, or from on-the-ground storage with manual transfer capability as well as be compatible with SARS equipment (AMC Regulation 70-17).

- capacity. The AFAS on board storage will be the greater of cruise range or 1.0 battlefield day usage. The FARV on board storage will be the greater of cruise range or 1.0 battlefield day. Fuel capacity reflects the following hypothesized fuel consumption rates:

** The following information is a summary of figures 2-5 and 2-6 in the FARV Refuel Transfer Technology Final Report dated 29 October 1993

OPERATING CONDITION		AFAS		FARV	
		Hrs/Km	Fuel (Liters)	Hrs/Km	Fuel (Liters)
Idle (under load)	Diesel	2.28	121	3.35	178
	Turbine	2.28	99	3.35	145
Idle (normal)	Diesel	5.90	105	3.0	53.2
	Turbine	5.90	155	3.0	79
Primary Road	Diesel	.19/4.7	32	.29/7.3	49
	Turbine	.19/4.7	43	.29/7.3	66
Secondary Road	Diesel	1.13/22.5	191	1.75/35.0	297
	Turbine	1.13/22.5	226	1.75/35.0	352
Cross Country	Diesel	1.96/19.6	223	3.07/30.7	349
	Turbine	1.96/19.6	291	3.07/30.7	456
Fording	Diesel	.5	38	.5	38
	Turbine	.5	41	.5	41
APS only	Diesel	12.0	75	12.0	75
	Turbine	12.0	164	12.0	164
Total - Battlefield Day	Diesel	24/46.8	784	24/73.0	1039
	Turbine	24/46.8	1019	24/73.0	1360
Cruise Total	Diesel	9.8/465	1009	9.8/465	1009
	Turbine	9.8/465	1133	9.8/465	1133

- transfer rate. The SARS refuel rate shall reduce "on-the-move" refueling time to two minutes, or less.

2.3.4 Refuel/Defuel Automation requirements.

2.3.4.1 Performance Requirements: The following performance requirements reflect a condensation of the criteria

specified by the FARV ORD.

2.3.4.1.1 Dock (FARV to AFAS/FARV to FARV). Docking is required to support the simultaneous transfer of ammunition components and fuel. The refuel/defuel mechanism must be compatible with the mechanical interfaces devoted to the transfer of LP and projectiles and may be integral to one or both. Once the two vehicles are within 7.6 meters (25 ft), docking must be completed in no more than two minutes under normal terrain conditions (±5°), and not more than three minutes under adverse terrain conditions (±10°). Docking will not be attempted in terrain conditions in excess of ±10°.

2.3.4.1.2 Connect and Lock. The automated refuel/defuel mechanism must mate and lock with the receiving vehicle receptacle without any personnel leaving the crew compartment(s) of either vehicle. When connected, the FARV fuel load is available for transfer. Pumping and filtering components are integral to the FARV refuel system.

The refueling receptacle shall be compatible with SARS equipment and the SARS nozzle, fitted with the refuel mechanism, must align six lugs and rotate 30° to ensure lock. A positive electrical connection will be established between the two vehicles and ground prior to the transfer of fuel in either direction.

2.3.4.1.3 Transfer. The automated refuel mechanism shall transfer fuel at not less than 132 to 190 liters per minute (LPM) (35 to 50 gallons per minute (GPM)) without exposure to contaminants under field conditions including hot engine condition. Fuel transfer must be compatible with SARS requirements including, but not limited to, a delivery pressure of .12 megapascals (MPa) (18 pounds per square inch (PSI)) and a closed vapor return capability. The quantity of fuel transferred will be as required by the receiving vehicle.

2.3.4.1.4 Undock. Upon completion of resupply activity, the FARV must completely undock (unlock, disconnect and pull away) in less than 30 seconds under normal conditions. In

the event of emergency, or rapid disconnect, undocking will be accomplished in less than 10 seconds with no damage to either vehicle and with minimal fuel spillage.

2.3.4.2 Automotive Capabilities

When in the stowed position (non-operable), the refuel/defuel mechanism shall be exposed to the following automotive operational requirements:

- vibration and shock resulting from cross country travel at speeds up to 48-60 KPH (29.8-37.3 MPH).

- angular deflection and stress resulting from traversing slopes up to 40%, assent and descent of slopes up to 60%, and climbing vertical obstacles 91-107 centimeters (cm) (36.2-40.9 inches (in.)) in height.

- water immersion resulting from fording water to a depth of 150 cm (59 in.).

- stress induced by towing, or being towed by a AFAS or another FARV.

The stowage position shall also be defined by the following operational requirements:

- visibility. The vehicle commander requires 360° day/night visibility, 90° lateral field with the remaining 270° available within two seconds. Close in vision is required to be within 3.1 meters (10 ft) of the perimeter of the vehicle and vertical vision shall be to 60° above the horizontal plane. In addition, there must be vision between crew members and between the crew and the cargo department.

2.3.4.3 Control and Monitor Requirements

The refuel/defuel mechanism and the fuel resupply subsystem must provide for automation of the refuel/defuel operation. Controls must be appropriate to initiate and monitor system activities. The following control requirements shall be met in addition to control and sensors for docking:

- conduct and manage refuel/defuel operations including the override of automatic functions at need

- support embedded diagnostic capability

- monitor system safety status

- support embedded training capability for operation and repair/maintenance training

- minimize single point failure and pinpoint such failure to the Line Replaceable Unit (LRU) level.

2.3.4.4 Miscellaneous Requirements

The following requirements are applicable to the refuel/defuel system:

- operational in temperatures from -46° to +49° centigrade (C) (-50.8° to 120.2° fahrenheit (F))

- be fully operational within 15 minutes from a cold start and within 45 seconds from a warm start

- be fully operable with the FARV APS

- be operated by personnel in Mission Oriented Protective Posture (MOPP) 4 protective clothing and operable and maintainable by the 5th to 95th percentile solder

- be capable of primary missions with two crew members for up to four hours.

2.4 LIMITATIONS, FROM "LESSONS LEARNED"

This section reiterates and consolidates the recommendations and findings of the FARV Fuel Transfer Technology Final Report, 29 October 1993. The referenced report documents the pros and cons of several in-service armored vehicles, including: the M1 and M1A1 Main Battle Tank; the M60 Tank; the M2/M3 and M2A1/M3A1 Fighting Vehicle; M113 Armored Personnel Carriers; M109 Self-Propelled Howitzer; M88A1 Armored Recovery Vehicle; the UH-60A Helicopter; and the AH-64A Helicopter.

2.4.1 Design Techniques to be avoided are specified as follows:

- Fuel tanks should not be located in crew compartment

- Single fuel tank

- Fuel supply line from only one tank to engine

- Permanent crossover connections with no cut-off valves between tanks

- No ullage or ullage in one tank only

- Fuel tank design and geometry that leads to major damage to the tank from hydraulic ram

- Fuel metering designs that heat fuel excessively

- Multiple tanks that must be filled through several receptacles

- Tanks fabricated from material that would shatter in case of a penetration

- Fuel tanks surrounded by pyrophoric materials such as aluminum

- No Automatic Fire Suppression System in the crew compartment and in the engine compartment

- No fuel tank safety venting system

2.4.2 Recommended design techniques or "solutions" are as follows:

- Fuel tanks should be located in separate compartments or behind armor on exterior portion of vehicle

- Multiple fuel tanks

- Redundant supply lines from several fuel tanks

- Ullage in each tank (5% minimum) to provide room for fuel expansion and minimize damage due to hydraulic ram in case of fuel tank penetration

- Fuel metering and return system design that heats fuel in tank only a minimal amount -- less than 6.7°C (20°F) above ambient temperature

- Multiple fuel tanks filled from a single point

- Multiple fuel fill points

- Tanks fabricated from high-strength material that limits the size of a penetration and would not shatter

- Fuel tanks surrounded by non-pyrophoric materials

- Automatic Fire Suppression System in the crew compartment and another system (preferably carbon dioxide) in the engine compartment

- Fuel tank safety venting system to prevent internal pressure build-up from rupturing the tank in case of fire

- Consider designing a fuel system in which the fuel lines are under vacuum, as in the UH-60A and the AH-64A helicopters

- Inclusion of self-sealing breakaway valves and/or fittings to contain fuel in case of damage or malfunction.

2.4.3 Priorities and Compromise

The FARV is primarily a logistics supply vehicle designed to maintain the peak battlefield capabilities of a self propelled artillery piece. By creating a resupply vehicle dedicated to rearming and reprovisioning a single armored artillery vehicle, the readiness and offensive striking power of that said same vehicle is greatly enhanced. Fire support, offensive and defensive, can be provided upon demand rather than at preplanned and supplied intervals.

By definition, the FARV is one half of an offensive set, made up of the FARV and the AFAS, whose mission is to supply fire support to advancing elements or to supply covering fire while elements reposition for defense. Therefore, space allocation within the confines of the FARV is first assigned to the storage and handling of munitions and LP; second, to the propulsion and main drive; third, to command, communication and control system (C3); fourth, to crew accommodation and safety; and, finally, to fuel storage and transfer.

The design recommendations arising from the "lessons learned" must be tempered by compromise dictated by the afore stated prioritization. Therefore, the fuel system design should adhere to the following parameters/goals:

1. Multiple fuel tanks shall be used

2. Each fuel tank shall be capable of receiving and supplying fuel separately, or in any combination, by the use of valving

3. Each tank shall be capable of being isolated from the system in case of battle damage

4. Fuel tanks shall not be placed within the crew or engine compartments

5. Each fuel tank shall maintain an ullage and water/sediment allowance of 5%, each, of the proposed tank capacity to reduce the effects of hydraulic ram and solids buildup

6. Refueling, or fuel up-load, shall be accomplished by the use of any single fuel receptacle or port

7. Avoid gravimetric fuel system design

8. Failure of any single LRU shall not disable the entire system.

SECTION THREE

FUEL SYSTEM DESIGN PARAMETERS

3.1 INTRODUCTION

3.1.1 Purpose

This section identifies, prioritizes and provides evaluation of componentry required to facilitate the following fuel related requirements:

- receipt (resupply) of fuel at the LRP
- storage of fuel
- SARS automated fuel upload and download
- manual fuel transfer
- onboard fuel system requirements

3.1.2 Parametric Basis

The definition, prioritization and evaluation of fuel system requirements is based on:

- mission analyses as presented by the ORD and the FARV REFUEL TRANSFER TECHNOLOGY FINAL REPORT dated 29 October, 1993

- SARS implementation as defined by AMC Regulation 70-17, Implementation of the Standard Army Refueling System, dated 20 July, 1989

- capabilities as defined by the Second Draft of the System Performance Specification for the Future Armored Resupply Vehicle (FARV), dated 7 July, 1993

- applicable guidance from the SARS FUEL SYSTEM DESIGN GUIDE FOR MILITARY REFUELABLE VEHICLES AND GROUND EQUIPMENT

- Human Factors Engineering requirements/considerations in accordance with MIL-STD-1472D and MIL-HDBK-759

- safety aspects as defined by NFPA requirements and MIL-STD-882C

3.1.3 Military Fuel System Requirements

Fuel systems designed for use on military equipment range from COTS and NDI systems to specially designed modular systems capable of operating in, and surviving, extreme battlefield and

combat environments. The AFAS and FARV mission profiles are such that the following unique conditions must be considered in the design of fuel systems used in these vehicles.

- multiple fuel fill modes (SARS, automatic upload, manual upload/download)

- rapid, hot, refueling in a battlefield environment (FARV to AFAS, FARV to FARV)

- severe shock and wide frequency of vibration induced by high speed road and cross country travel as well as ballistic impact

- wide range of operational attitude (from the horizontal) resulting from traversal of longitudinal slopes up to 60% and lateral slopes up to 40%

- water immersion up to 150 cm (59 in.) when fording water courses

- structural and protective platform distortion induced by the traverse of uneven terrain and obstacles

- extremes in operational temperature (-46° to +49°C (-50.8° to 120.2°F))

- long term storage (non-use)

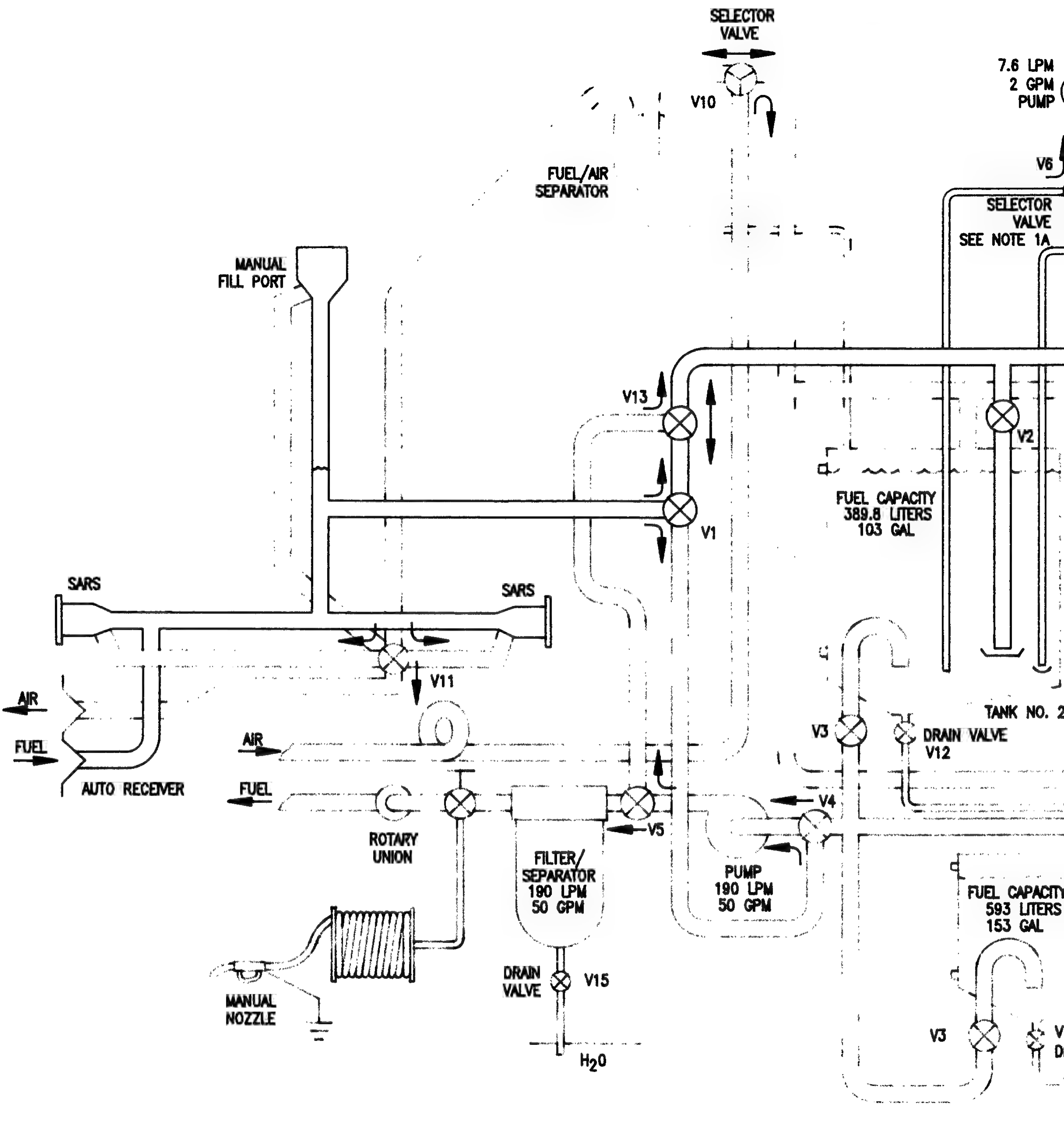
3.1.4 Organization

While the fuel system for the FARV is considered a single sub-system to the FARV, for the purpose of this report, the fuel system is divided into the following functional modules:

I. Fuel Storage Module (FSM)
II. Vehicle Fuel Module (VFM)
III. Fuel Transfer Module (FTM)
IV. Electronic/Electrical Interface Module (EEIM)

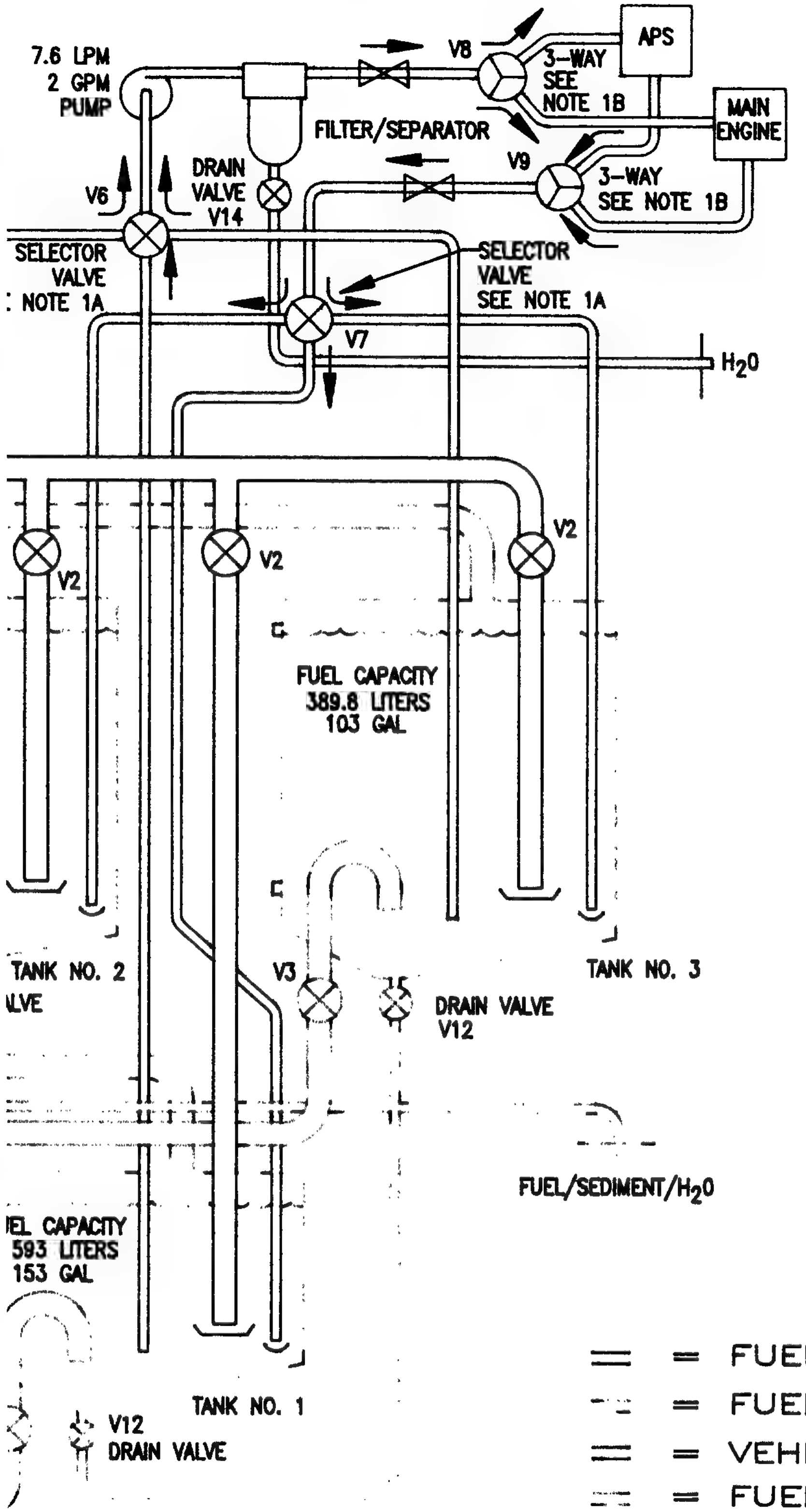
3.2 SYSTEM DEFINITION

AMC-R 70-17 defines a vehicular fuel system as "all the necessary components, organic to the vehicle, which receive, store, and deliver fuel to the engine. This includes the fuel tanks, fuel inlet receptacles, fuel transfer pumps, strainers, filters, fuel/water separators, fuel heaters, and associated tubing, hoses, fittings, crossovers, and vents. It does not include the fuel injection pump or ancillary fuel consuming equipment such as smoke generators and personnel heaters." This section defines and identifies the design requirements applicable to components in each system module. For a schematic representation of the FARV fuel system, see Figure 1.



FARV REFUEL/DEFU

FIGURE NO



NOTES:

1. VALVE OPERATION SHALL BE AS FOLLOWS:

   A. 4-WAY SELECTOR VALVES

POSITION 1	TANK NO. 1
POSITION 2	TANK NO. 2
POSITION 3	TANK NO. 3
POSITION 4	CLOSED

   B. 3-WAY SELECTOR VALVES

POSITION 1	APS
POSITION 2	MAIN ENGINE
POSITION 3	BOTH

= FUEL STORAGE MODULE—FUEL LINES
= FUEL STORAGE MODULE—VENT LINES
= VEHICLE FUEL MODULE
= FUEL TRANSFER MODULE

EFUEL SYSTEM

NO. 1

3.2.1 Fuel Storage Module (Figure 1, color code blue)

The FSM components provide the means by which the FARV may be refueled at the LRP, or "on-the-move", and the means to retain the fuel until it is consumed or transferred. The components include: fuel tank(s), or cell(s); fuel inlet receptacles (SARS and manual); tubing and hose; fittings, connectors and couplings; crossovers and vents; fuel tank/cell heaters; sensors (high and low fuel level, pressure, water, contaminant, temperature); and valving (flow diverting, check, shut-off, drain).

3.2.1.1 Fuel Tanks

The fuel tank(s), or cell(s), contain the fuel required by the FARV on-board systems and the resupply quantity to support the AFAS. Depending upon the allocation of space, single or multiple fuel tanks may be present within the armored confines of the vehicle. The fuel tanks shall be filled through one receptacle at a time, either manually, utilizing gravimetric flow, or under pressure. Each fuel tank will incorporate provisions for sensing devices, drains, vents and safety devices, as well as fuel supply and return ports.

3.2.1.1.1 Total Capacity

The total capacity of the fuel tank(s) shall be equal to one battlefield days' requirement (1,360 liters/359 gallons) plus 5% per tank for ullage and 5% per tank for sediment. This equates to a total fuel storage capacity of 1,494 liters (394.9 gallons).

3.2.1.1.2 Integrity

The level of tank integrity is driven by the mission and battlefield environment to which the FARV is exposed. A high-strength material shall be used in fuel tank fabrication in order to lessen the probability of rupture, shattering and cracking. Baffling shall be integrated into the tank design to reduce free surface movement and fuel aeration. The tank joints will be welded, brazed or similarly closed to prevent leakage. Soft solder, glues and crimping will not be used as techniques for joint closure.

3.2.1.1.3 Location and Shape

The location and shape of each tank is subject to space availability. However, fuel tanks should not be placed in close proximity to the crew positions nor should any tank be positioned above the engine. Unusual shaped tanks are more desirable than tanks directly

exposed to crews or engine. The shape of each tank shall minimize agitation of the tank bottom, provide for a "cone-down" bottom or a sump, and allow for fuel expansion. The location of each tank shall also be conducive to permitting access to valving and sensors attached, or mounted within, without decreasing survivability. Fuel tanks with capacities less than 75 liters (20 gallons) are to be avoided.

3.2.1.2 Fuel Inlet Receptacles (Fill Ports)

Fuel inlet receptacles permit the FARV to be fueled by automated and manual means, in differing environments.

3.2.1.2.1 Manual Fuel Fill Port

The manual fill port shall permit uploading of fuel by dismounted personnel. Nozzles up to 10.2 cm (4 in.) in diameter can be employed to refuel the FARV using the manual fill receptacle as well as "Jerry Cans". The manual fill port design shall incorporate a locking cover, or cap, with integral seals that ensure against contamination when the cap is closed and secured. The cover/cap shall be armored and the housing around the cap shall incorporate a sensor which senses port closure. The cover shall be operable in adverse environments and by personnel in MOPP 4 Protective clothing.

When filling the FARV by the manual port, air and vapors escape the system from around the filling nozzle or can. When closed, the manual fill port aperture shall not vent to atmosphere. A labyrinth valve plug in the cap permits the controlled aspiration of air. This provides a soft gas compression column which absorbs hydraulic ram effects resulting from rapid valve closure during SARS "on-the-move" refueling.

3.2.1.2.2 SARS Receptacle

The SARS receptacle, of which there are two, permits two minute refuel and four minute defuel maneuvers to be accomplished, both manually and automatically. The receptacle and the SARS manifold are sized for 757 LPM (200 GPM) transfer rates in accordance with draft SAR Design Handbook. Each SARS receptacle is protected by an armored cover that is operable from within the crew space. A sensor is integrated into the cover housing which monitors closure.

3.2.1.2.3 Accessibility

The SARS fuel inlet receptacles shall be accessible by personnel on the ground. The SARS Refuel/Defuel receptacle will not be obstructed by turret, robotics, or any similar protuberance. Both the SARS and Manual Fill Receptacles shall incorporate, in their design, armored covers that protect the ports from battle damage as well as the environments. These covers shall be operated from within the vehicle, thus preventing unauthorized use or tampering. The Manual Fill Port armored cover or housing shall incorporate a labyrinth vent which will permit the fuel system to vent to atmosphere. The labyrinth shall not allow the entry of water, flashover, and shall be filtered against airborne contaminants.

3.2.1.3 Tubing and Hose

The tubing and hose used in the FSM will connect the fuel tank(s), receptacles and vent components. The tubing and hose will be sized as appropriate to refuel in two minutes or less.

3.2.1.3.1 Use/Application

Rigid tubing shall be used in the design of the Fuel Fill Manifold and in similar areas required to transfer large quantities of fuel in short periods of time. Where feasible, tubing shall be implemented in the design of crossovers. Sharp bends shall be avoided.

Flexible hose, metallic or elastomeric, shall be used in the Fuel/Air Vent sub-system. It shall also be employed to facilitate the use of spaces otherwise difficult to access.

Tubing and hose shall be grounded to ensure against the propagation of Electromagnetic Pulse (EMP) to, or from, more sensitive electrical/electronic components (valving/sensors).

3.2.1.3.2 Materials

The materials used in the fabrication of tubing and hose shall not be susceptible to corrosion when subjected to fuel or water. When connected or joined, the methods employed shall ensure integrity equal to, or surpassing, that of the material. Copper, zinc or vanadium coatings shall not be used where directly

exposed to fuel. Coatings shall not degrade when exposed to fuel, water, or Nuclear, Biological, Chemical (NBC) decontamination chemicals.

3.2.1.4 Fittings/Connectors/Couplings

The fittings, connectors and couplings required by the FSM will vary in size and capacity depending upon their placement within the system. The use of fittings, connectors and couplings will be kept minimal. Where used, the item will expedite the removal of repairable components such as valves and/or sensors. Exposure to fuel, water and NBC decontamination agents will not degrade, nor adversely effect, the components' capabilities.

3.2.1.5 Crossovers and Vents

Crossovers and vents shall be incorporated, as necessary, in a gravimetric fuel system to ensure that the fuel flow to each tank, in a multiple tank system, is roughly equal and that the last tank filled is the tank closest to the receptacle. When refueling with a pressurized system, each tank shall incorporate venting adequate to allow the appropriate amount of vapors and air to return to the vented fill port. All vents shall be exhausted at a common point. Crossovers and manifolds shall incorporate the valving required to isolate the tank(s) in the event of damage.

3.2.1.6 Filtration of Fuel

The FARV will receive fuel under controlled conditions that ensure fuel integrity. Therefore, fuel filtration and conditioning is not required for newly received fuel. The VFM and the FTM, both, shall include filtration and water separation components which insure that fuel used by the FARV, or fuel off-loaded, is free of contaminants.

3.2.1.7 Heaters

The design of the fuel tank(s) permits the accumulation of sediment and/or water to a value of 5% of the tank capacity. Heaters are required to prevent water from freezing in the bottom of the tank or the drain valve, either of which could result in fuel leakage and component failure. Fuel tank (cell) heaters also ensure against fuel additive separation due to excessive cold. The heaters shall be capable of ensuring fuel delivery at not less than 5°C (41°F).

3.2.1.8 Sensors

The sensor requirements of the FSM include the determination and monitoring of fuel level, tank pressure, fuel temperature, armored cover status and water/sediment depth. The sensing devices shall not be degraded by exposure to fuel, water or NBC decontamination chemicals. Sensors used to monitor fuel tank depth shall be accurate to within 5%. Pressure sensors shall be accurate within .02 MPa (2 PSI). Temperature sensors shall be accurate to ±0.7°C (33.26°F).

3.2.1.9 Valving

The valving included in the FSM is of two types; automatic or electrically activated. The automatic valving activates when an unsafe condition is detected, such as extreme pressure or temperature. The electrically activated valve responds to signals issued either by the Mission Management and Control System (MMCS) or the EEIM. The activities performed by the electrically activated valves are related to fuel flow and direction.

3.2.2 Vehicle Fuel Module (Figure 1, color code red)

The VFM components ensure that fuel consumed by the FARV is free of contaminants, including water, that would be detrimental to vehicle operation. The components include but are not limited to: pump(s); sediment and precipitant filters; water separator(s); tubing and hose; fittings, connectors, and quick-connect couplings; sensors (flow, pressure, temperature); and valving (check, flow diversion, shut-off).

3.2.2.1 Pump(s)

The VFM fuel pump provides fuel to the MPU and the APS. It is capable of operating at the environmental temperature extremes of -46°C to +49°C (-50.8°F to 120.2°F). The pump motor shall be powered by 24 volts, direct current (VDC). The pump assembly shall be a sealed, explosion-proof, unit, fused against electromagnetic interference (EMI)/EMP, and shall not be degraded by exposure to small amounts of water suspended in the pumped fuel or exposure to NBC decontamination chemicals. The pump shall be capable of continuous operation of not less than 10,000 hours.

3.2.2.1.1 Capacity

The VFM fuel pump shall be capable of supplying 6.1 to 6.4 LPM (1.6 to 2.0 GPM), continuously, as defined by the FARV Refuel Transfer Technology Final Report, augmented by 25% to allow for flow loss through

orifices, aperatures, valves and restrictions made necessary by fuel line routing and control.

3.2.2.1.2 Accessibility

The VFM fuel pump will be accessible from the engine compartment. The sealed pump shall incorporate quick-connect couplings to facilitate removal, repair and replacement.

3.2.2.2 Filters, Sediment and Precipitant

The VFM fuel filter shall be a, free-flow, replaceable element type. The replaceable element shall not permit passage of particles or solid contaminates exceeding 10 microns in size. The filter housing shall incorporate a by-pass and sensor in order to not cause engine shut-down when the filter is "plugged". Sensors shall also sense the pressure differential between the filter fuel inlet and outlet to provide data to the MMCS relating to service life and maintenance requirements. The filter may incorporate water separation in its design. However, incorporation of water separation into the design of the filter shall not decrease the filters' efficiency.

3.2.2.2.1 Capacity

The fuel filter capacity shall not be less than 7.6 LPM (2 GPM). The unit shall be capable of withstanding pressure differentials between its inlet and outlet of .51 MPa (75 PSI). The filter shall remove organic and inorganic particles.

3.2.2.2.2 Accessibility

The filter should be readily accessible for repair and replacement of the filter element. It shall be functionally located between the VFM fuel pump and the MPU and the APS. A drain should be incorporated to permit drain-down coincident with filter element change. Placement of the filter assembly shall be within the ballistic armor protection of the vehicle. The filter shall be accessible from the engine compartment.

3.2.2.3 Water Separator(s)

The conditions to which the FARV is exposed necessitate the inclusion of one, or more, water separation devices in the fuel system. Extended periods of storage and temperature change will cause water to condense out the air volume within the tanks. Water must be removed from the fuel prior to its use by the MPU or the APS. Provisions for the sensing of

water level are to be included in the design of the unit as well as valving to drain the filter to either a holding tank or the vehicle exterior. The water separator may be combined with the filter unit. However, combining filtration with water separation shall not degrade the efficiency of the separation process.

3.2.2.3.1 Capacity

The water separator shall be capable of removing emulsified water of up to 0.5% by volume. Fuel flow through the separator shall be not less than 7.6 LPM (2 GPM).

3.2.2.3.2 Accessibility

The water separator shall be readily accessible for repair and replacement. It shall be functionally located between the VFM fuel pump and the MPU and the APS. The unit shall be accessible from the engine compartment.

3.2.2.4 Tubing and Hose

Tubing and hose used in the VFM will connect the fuel tank(s) to the VFM fuel pump; the VFM fuel pump to the filter and separator; the filter and separator to the MPU or the APS; and will provide the medium for fuel return to the tank(s) and return unused fuel to the fuel tanks via fuel valving. The inside diameter of the tubing or hose shall be not less than 10.3 millimeters (mm) (13/32 in.) nor more than 15.8 mm (5/8 in.).

3.2.2.4.1 Use/Application

Rigid metallic tubing shall be used for areas not subject to excessive vibration and to avoid the possibility of rupture due to excessive pressure (hydraulic ram effect) resulting from rapid valve closure. Routing of rigid tubing shall avoid sharp bends.

Flexible hose, metallic or elastomeric, shall be implemented to isolate sources of vibration as well as to facilitate the use of space not conducive to rigid tubing. The tubing and hose shall be capable of withstanding 1.7 MPa (250 PSI).

Tubing and hose shall be grounded to alleviate the build-up of a static charge and to ensure against propagation of EMI/EMP to, or from, more sensitive electrical/electronic components (valving/sensors).

3.2.2.4.2 Material

Tubing and hose assemblies shall be fabricated from materials not susceptible to corrosion when subjected to fuel or water. When connected, or joined, to similar or unlike material, the methods employed shall ensure integrity equal to, or surpassing, that of the material. Copper, zinc, or vanadium materials or coatings may not be used where directly exposed to fuel. Coatings shall not degrade when exposed to fuel, water, or NBC decontamination chemicals.

3.2.2.5 Fittings/Connectors/Couplings

Fittings, connectors, and couplings required by the VFM shall be standardized to one size for ease of repair. The use of fittings, connectors and couplings will be kept to a minimum. Where used, the item will expedite the maintenance, removal and replacement of repairable components. Exposure to fuel, water, and NBC decontamination agents shall not degrade the components' capabilities nor reduce its' life.

3.2.2.6 Sensors

The sensor requirements of the VFM include the determination of fuel temperature and pressure and the monitor of filter and water separator status. The sensing devices shall not be adversely effected by exposure to fuel, water, or NBC decontamination chemicals. Pressure sensors shall be accurate to .02 MPa (2 PSI) and temperature sensors shall be accurate to within 0.7°C (33.26°F). The status sensors used to monitor the filter(s) and separator(s) shall be accurate to within 10%.

3.2.2.7 Valving

Valving incorporated into the design of the VFM shall be electrically energized. An electrically activated shut-off valve is activated by the MMCS when fire is detected in the engine compartment. A diverter valve is used to divert fuel flow to either the MPU or the APS. Flow valves are used to control from which tank fuel is supplied and returned, thus reducing fuel temperature elevation to unacceptable levels.

3.2.3 Fuel Transfer Module (Figure 1, color code green)

The FTM components ensure that fuel is delivered to the AFAS via the robotic arm, or another FARV, free of contaminants, conditioned and at such pressures and volumes as to not impede operational status or survivability. The components include but are not limited to: fuel transfer pump; sediment and contaminant

filters; water separators; tubing and hose; fittings, quick-connect couplings and rotary joints/unions; sensors (flow, pressure, temperature); and valving (flow diversion, shut-off).

3.2.3.1 Fuel Transfer Pump

The FTM fuel transfer pump provides the means by which the fuel contained within the FARV onboard tanks is transferred, on demand, to an AFAS or another FARV. The fuel pump shall be a centrifugal type, driven by a 24 VDC electric motor. The pump assembly is capable of operation at temperatures from -46°C to +49°C (-50.8°F to 120.2°F). The pump shall incorporate sealed bearings and be fabricated of, or coated with, material not subject to degradation or corrosion when exposed to fuel, water, or NBC decontamination chemicals. The 24 VDC motor shall be of sealed, explosion proof construction and fused against EMI/EMP. The motor shall be rated "continuous duty" for not less than 5,000 hours.

3.2.3.1.1 Capacity

The FTM fuel transfer pump shall provide fuel at a rate of not more than 190 LPM (50 GPM) at .34 MPa (50 PSI). Fuel inlet and outlets shall be 2 inch ID.

3.2.3.1.2 Accessibility

The FTM fuel transfer pump shall be accessible for repair and replacement. No routine maintenance shall be required by the pump. Access shall be gained through panels and bulkhead hatches.

3.2.3.2 Sediment and Contaminant Filters

Sediment and contaminant filters are required to ensure that the fuel off-loaded to an AFAS or a FARV is free of particles or substances that jeopardize the operational capability of the receiving unit. The filter(s) shall be free-flow, replaceable element type. The replaceable element shall not permit passage of particulate matter, organic and inorganic, exceeding 10 microns in size. The filter housing shall incorporate a pressure by-pass and sensor to ensure against loss of fuel flow should the filter become "plugged". Sensors shall also sense the pressure differential between the fuel inlet and outlet of the filter to provide data to the MMCS relating to service life and maintenance requirements. The filter(s) may incorporate water separation into its design. However, incorporation of water separation into the design of the filter shall not degrade the effectiveness of the filter.

3.2.3.2.1 Capacity

The filter shall have a flow rate of not less than 190 LPM (50 GPM) and be capable of withstanding pressure differentials between its inlet and outlet of not less than .51 MPa (75 PSI). The replaceable filter element shall not permit passage of particulate matter, organic or inorganic, exceeding 10 microns in size.

3.2.3.2.2 Accessibility

The filter element shall be readily accessible for replacement. Provisions will be made to allow the filter housing to be drained down prior to element removal. The fuel drained from the housing will be returned to a fuel tank. Valving will be incorporated into the design to eliminate the possibility of gravimetric fuel flow during regular maintenance.

3.2.3.3 Water Separator(s)

Battlefield conditions, the environmental envelope of deployment, and extended storage may contribute to the amount of water suspended and emulsified in the fuel. Clean, uncontaminated fuel must be delivered to the AFAS at the rates required to ensure operability and survivability. The design of the water separator shall incorporate provisions for the sensing of water, water level, and draining the water from the housing. The water separator may be combined with the filter unit. However, combining filtration with water separation shall not degrade the efficiency of the separation process.

3.2.3.3.1 Capacity

The water separator shall be capable of removing emulsified water up to 0.5% by volume. The rate of fuel flow through the separator shall be 130-190 LPM (30 to 50 GPM) at not less than .17 MPa (25 PSI).

3.2.3.3.2 Accessibility

The water separator shall be accessible for repair and replacement. A drain valve will evacuate the water contained in the separator housing to an overboard port or to a storage tank. If separate, the separator will be functionally located after the fuel filter but prior to the transfer interface with the robotic arm.

3.2.3.4 Tubing and Hose

The tubing and hose required by the design of the FTM will connect the fuel tank(s) to the FTM fuel transfer pump; the fuel transfer pump to the fuel filter(s); the fuel filter(s) to the fuel/water separator(s); and the fuel/water separator to the interface with the robotic arm. The tubing and hose shall be sized as appropriate to a fuel rate of not less than 190 LPM (50 GPM) at not less than .17 MPa (25 PSI).

3.2.3.4.1 Use/Application

Rigid metallic tubing shall be used for the majority of the design for the FTM except where flexible tubing is required to isolate sources of vibration or to provide for ease of repair/replacement. Sharp bends are to be avoided in rigid tubing. Coaxial tubing and hose may be used to save space. Tubing and hose shall be grounded to ensure against the propagation of EMP to, or from, more sensitive electrical/electronic components (valving/sensors).

3.2.3.4.2 Material

The materials used in the fabrication of tubing and hose shall not be susceptible to corrosion when exposed to fuel or water. When connected or joined, the methods employed shall ensure integrity equal to, to surpassing, that of the material. Copper, zinc or vanadium coatings shall not be used where directly exposed to fuel. Coatings shall not degrade when exposed to fuel, water, or NBC decontamination chemicals.

3.2.3.5 Fittings, Quick-Connect Couplings, and Robotic Arm Interface Components

The fittings, quick-connect couplings, and robotic arm interface components required by the FTM shall be sized for ease of repair and maintenance. The use of such connecting devices shall be limited to design requirements related to repair and replacement of system module components. Exposure to fuel, water, and NBC decontamination chemicals shall not degrade, nor adversely effect, the components' capabilities.

3.2.3.6 Sensors

The sensor requirements of the FTM include the determination and monitoring of fuel pressure and temperature, filter and separator status, and confirmation of fuel flow and valve operation. The sensing devices shall not be degraded by exposure to fuel, water, or NBC decontamination

chemicals. Pressure sensors shall be accurate to within .0136 MPa (2 PSI). Temperature sensors shall be accurate within 0.7°C (1.2°F).

3.2.3.7 Valves

Valving incorporated into the design of the FTM includes electrically operated/activated fuel flow diversion and control (shut-off) valves and vapor (vent) return valving. The valves respond to signals from the MMCS via the EEIM.

3.2.4 Electronic/Electrical Interface Module

The EEIM components provide an interface for MMCS communication. The EEIM translates command signals into the voltages and power ratings needed to activate electromechanical fuel control devices. It also pre-processes sensor information, averaging values as required, to present singular data to the MMCS and operating personnel. The components are likely to include but not be limited to: contactors (various sizes); latching relays; DC to DC convertors; analog to digital convertors; signal amplifiers; Liquid Crystal Displays (LCD); filters and filtered connectors; and signal processor(s).

3.2.4.1 Contactors

Contactors are electromechanical switching devices which can transfer large currents with low control voltage/current.

3.2.4.1.1 Application

Contactors shall be used to switch the relatively high currents required by the VFM and FTM pumps, solenoid valves, and motor controlled valves. These pumps and controls are used to transfer fuel from the on-board fuel tank(s) to either the MPU and/or the APS, to another on-board fuel storage tank (cell); or to the robotic fuel components for transfer of fuel to an AFAS or another FARV. Direct Current (DC) switched by the contactors may range from 0.6 amperes (AMPS), for solenoid operated valves, to 78 AMPS, for the 190 LPM (50 GPM) pump motor.

3.2.4.2 Latching Relays

Latching Relays require a momentary signal to latch and hold contacts closed until a second signal is applied, usually to a second coil, to unlatch the relay. These relays are useful when a long term closure with no continual power usage is desired.

3.2.4.2.1 Application

Latching Relays may be used in place of contactors where the current requirement is less than 5 AMPS and it is desirable to provide a second signal to discontinue the particular activity. A latching relay may be employed to initiate operation of the VFM pumps.

3.2.4.3 Convertors, DC to DC

Convertors, DC to DC, are used to increase or decrease the supply voltage to levels required by different circuits in a device.

3.2.4.3.1 Application

DC to DC convertors shall be used on the printed circuit board(s) to vary direct current voltage to certain integrated components. One or more printed circuit boards may be required to contain and mount the necessary electronic components required by the EEIM control logic.

3.2.4.4 Convertors, Analog to Digital

Analog to digital (A/D) convertors change an analog signal to a digital equivalent that can be processed by a computer and/or be presented on a digital display.

3.2.4.4.1 Application

Sensor data is converted from analog to digital by A/D convertors prior to its being processed by the Central Processing Unit (CPU) and/or forwarded to the MMCS. Sensors that provide differentiated current relative to pressure, temperature, and/or volume will require analog to digital signal conversion prior to data processing.

3.2.4.5 Signal Amplifiers

Signal amplifiers are normally used to increase the current output from analog circuits. However, they also can be used as amplifiers to precondition circuits that drive high DC loads.

3.2.4.5.1 Application

Signal amplifiers shall be used to amplify weak signals to permit differentiation from similar digital data. They may be required to assure arrival of data that travels extended distances through wire and cable.

3.2.4.6 Liquid Crystal Displays (LCD)

LCD's are low-current devices that can display any information desired,in alpha/numeric form. These devices can be used as primary or remote annunciators to provide operating personnel with information essential to the successful operation of the system.

3.2.4.6.1 Application

An LCD may be used to convey visual messages to FARV crewmembers concerning fuel system status. The same information will be communicated to the MMCS for further action, as required. The LCD will be augmented by an audible alarm should the message content reflect a dangerous situation.

3.2.4.7 Signal Filters and Filtered Connectors

Filters and filtered connectors both serve similar functions; to reduce or eliminate unwanted noise signals that can disrupt the normal operation of electronic equipment. They are placed on power and/or ground leads, but never on data lines in high-operating speed systems.

3.2.4.7.1 Application

Signal filters and filtered connectors shall be used to minimize the effects and transfer of EMI to integrated circuit components and the signal processor. Communication interfaces between the sensors and the printed circuit board(s) shall be filtered shielded and grounded to lessen the propagation of EMP/EMI.

3.2.4.8 Signal Processor(s)

The signal processor is the primary device in a computer that processes and directs data as specified by the program. It, along with required ancillary circuitry, can initiate warnings, cause data to be displayed, and direct the operations of equipment.

3.2.4.8.1 Application

The signal processor(s) integrated into the design of the EEIM shall correlate and compare incoming sensor data to the dictates of the firmware (program). The resulting data shall be forwarded to the MMCS for further comparison and any resultant action. Additionally, the processor(s) shall respond to commands issued by the MMCS and shall initiate the proper sequence of events required to achieve the appropriate result.

SECTION FOUR

SYSTEM ARCHITECTURE

4.1 SCOPE

This section describes in detail the design criteria to which the conceptual fuel system adheres. Each item of componentry is defined in generic terms, whether fabricated or commercially available, that reflect minimum acceptance values (for examples of commercial components that reflect the requirements specified herein, see Appendix B). The FARV fuel system (see Figure 2) is divided into four functional modules, the operation of which is further defined in its subparagraph. The four Modules are the Fuel Storage Module (FSM), the Vehicle Fuel Module (VFM), the Fuel Transfer Module (FTM), and the Electronic/Electrical Interface Module (EEIM). The locations depicted are as presented in ETOA (dated 9 JULY, 1993).

4.1.1 Criteria for selection

The basis for component selection was derived from the probable accessibility applicable to the majority of the FARV Fuel System components. A combat vehicle is difficult to gain access to by design. Otherwise, infantry could approach the vehicle and immobilize it with relative ease. Additionally, the FARVs' mission requires it to transport flammable and highly explosive logistic supplies from the LRP to the tactical position of the AFAS. Exposure of these volatile logistic supplies to various terrain features and small arms fire necessitates the inclusion of partitions and bulkheads to protect the main propulsion unit and crew. These partitions and bulkheads further reduce accessibility.

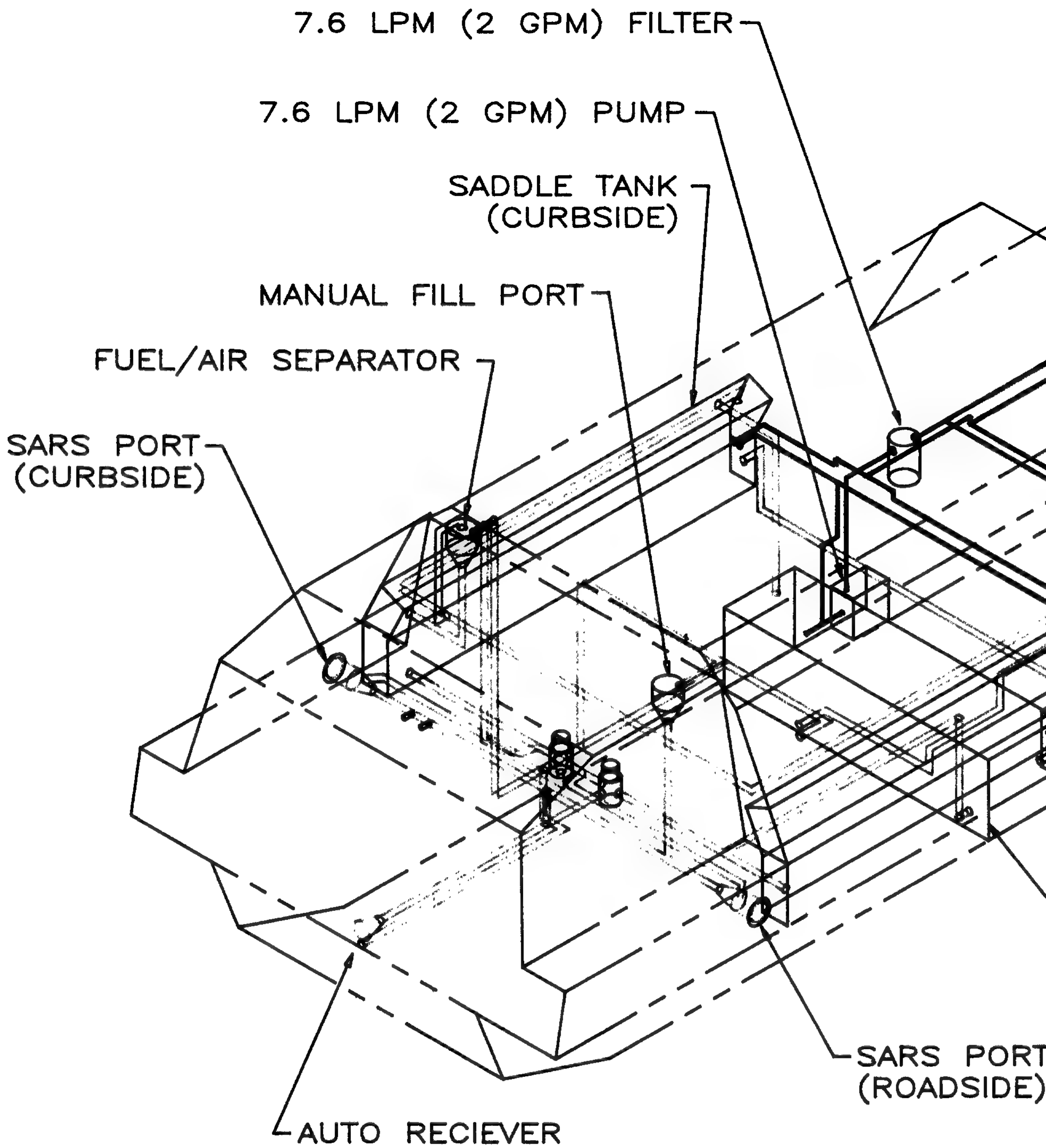
The following criteria is the basis for the selection of the commercial components exemplified for use in the FARV Fuel System. The criteria are listed in order of importance, from the most important to the least important:

- Performance

  The items have to perform at a level sufficient to meet mission requirements.

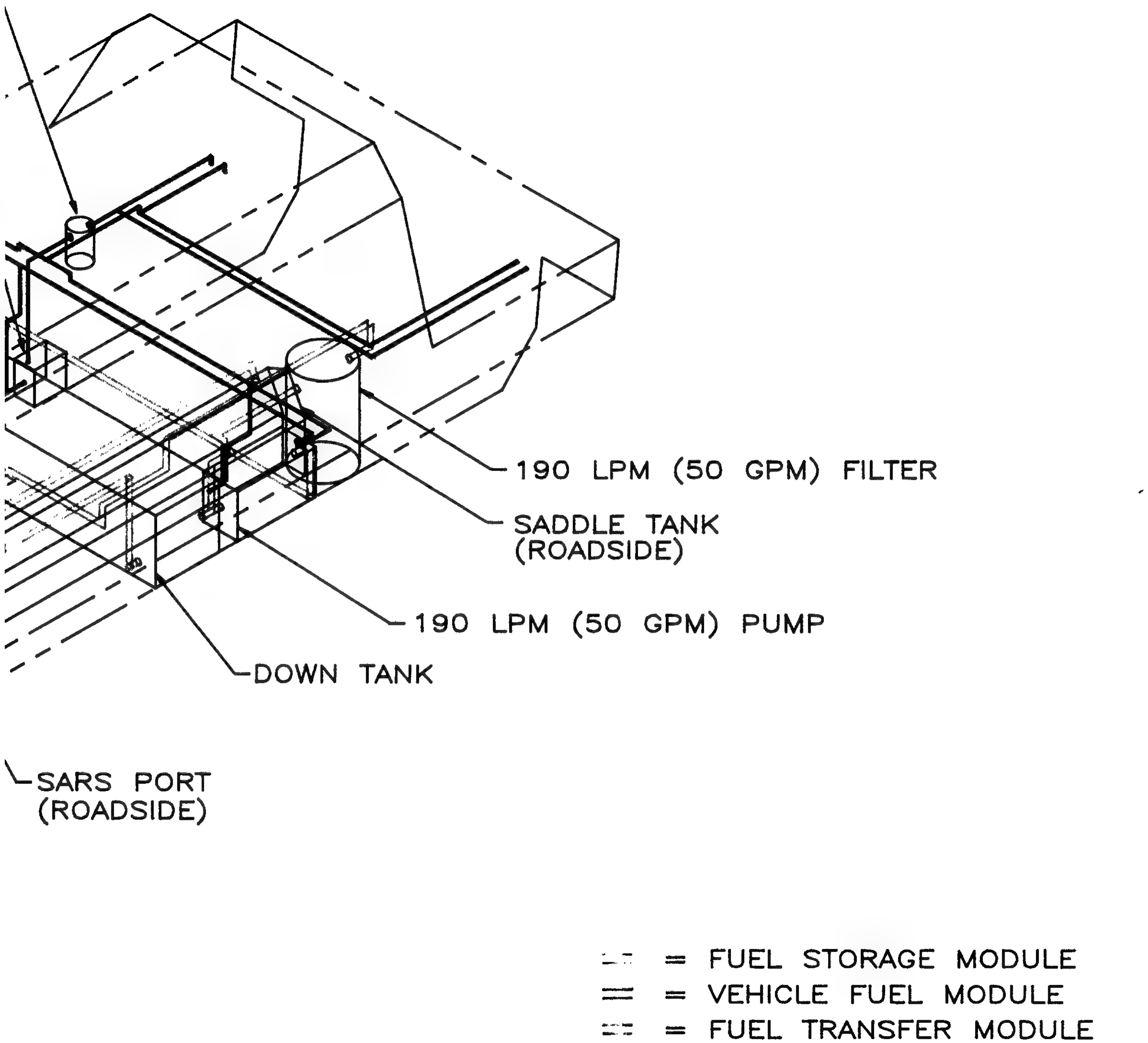
- Reliability

  Due to space limitations inherent to the FARV, access to the fuel system components for repair/ replacement will be limited. Therefore an MTBF of not less than 10,000 hours was deemed appropriate.



FARV FUEL SY

FIGURE 2



UEL SYSTEM
URE 2

- Commonality

  To the extent feasible, items should have multiple usage within the FARV Fuel System, or be the same as, or similar to, items already in use by the military on similar combat, or support, vehicles.

- Availability

  When possible, the items should be standard COTS, or NDI, components to provide the most readily available item.

- Size and weight

- Cost

4.1.2 Accessibility Statement

Unless otherwise noted, the following is applicable to all valves and sensors:

> The valves and sensors shall not require normal maintenance or adjustment to ensure their operation. Their Mean Time Between Failure (MTBF) shall not be less than 10,000 hours of continuous operation.
>
> The design of the system precludes ease of access. When necessary, the entire valve or sensor may be replaced in less than one hour by removing one, or more, access plates. The removal of a failed, or suspect, LRU shall not necessitate the removal or loosening of an adjacent component or assembly. The logistic load of munitions may be required to be removed to accomplish repair.

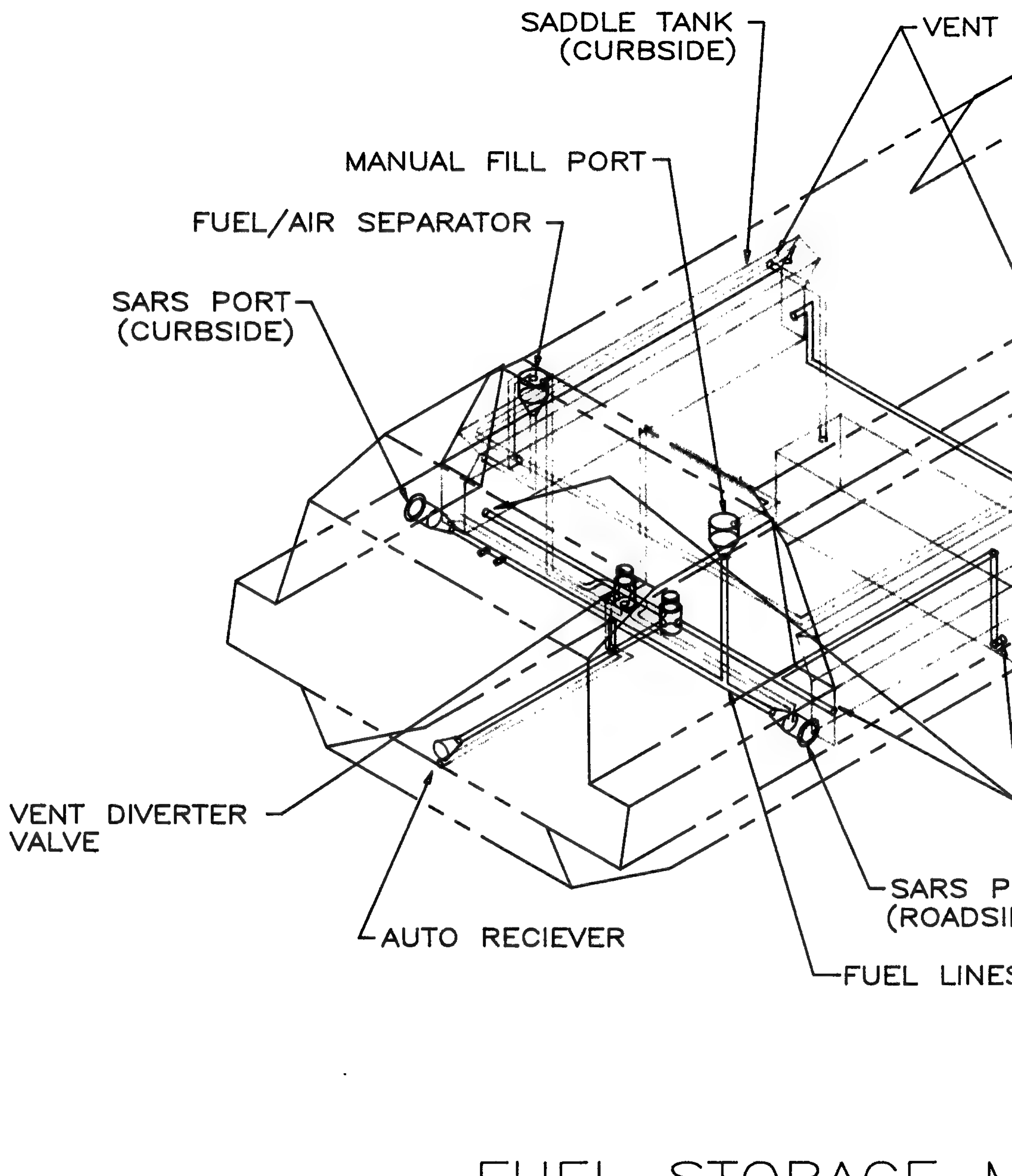
4.1.3 Materials Statement

Unless otherwise noted, the following is applicable to all valves and sensors:

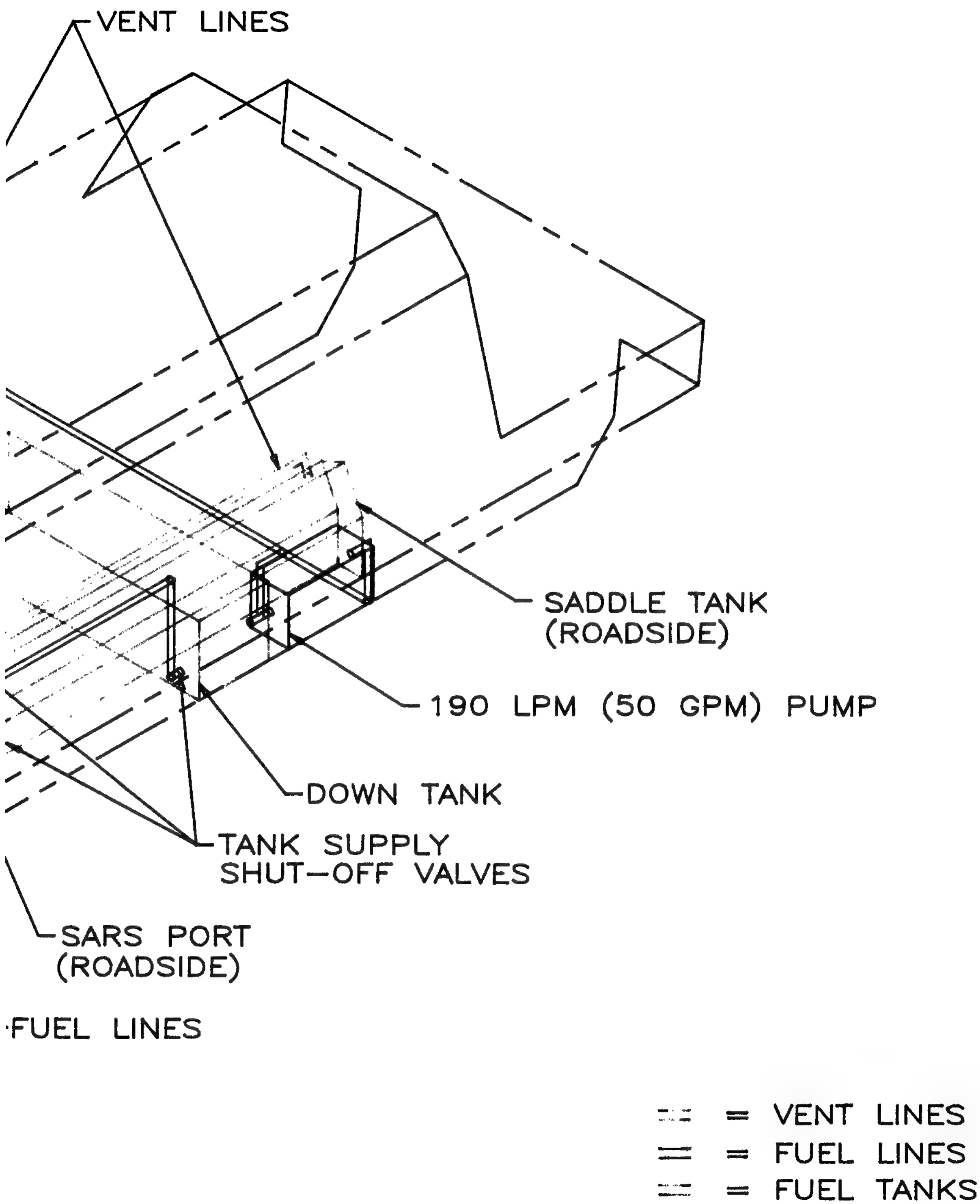
> Valve and sensor materials are not degraded by contact with fuel, water or chemical decontaminant.

4.2 FUEL STORAGE MODULE (Ref. Figure 3 and 8)

The FSM incorporates fabricated and commercially available components that accept, condition and store the fuel aboard the FARV. The FSM adheres to the requirements of the SARS FUEL SYSTEM DESIGN GUIDE FOR MILITARY REFUELABLE VEHICLES AND GROUND EQUIPMENT as applicable for SARS refuel on-the-move capabilities. The FSM includes the componentry necessary to permit up-loading of fuel to the FARV via SARS, manual and automated methods.



FUEL STORAGE M
FIGURE 3



AGE MODULE
RE 3

4.2.1 Receptacles, Fuel

The FARV is fitted with fuel receptacles which enable the vehicle to be up-loaded manually, by SARS equipped LRP's and by another FARV, automatically.

4.2.1.1 Manual Fill Port

The Manual Fill Port allows the FARV to be refueled by disembarked personnel using conventional refueling apparatus and "gas station methods". It also permits emergency, unpowered, refueling using any conveyance which can hold fuel (ie; "Jerry" Cans, buckets, etc.). The Manual Fill Port enables personnel to fuel the FARV using gravimetric methods.

4.2.1.1.1 Design (Ref. Figure 4a)

The design of the Manual Fill Port includes an armored cover with a circular port seal. The armored cover is hinged and protects the aperture, when closed, from the propogation of fire and concussive pressure. The design of the cover incorporates a labyrinth vent plug which permits the system to vent during periods when the system is not in the defuel/refuel modes. When open, the cover will not obstruct, or interfere with the use of, any fuel transfer device.

The Manual Fill Port housing incorporates a switch/ sensor that is activated when the cover is opened. This sensor is integrated with the latching solenoid which secures the cover during normal FARV operation. The sensor enables the EEIM to determine the correct position for the vent valve during manual fueling of the FARV.

The Fill Port aperture is approximately 76 mm (3 in.) in diameter and 152 mm (6 in.) in depth. The base of the port tapers to 51 mm (2 in.) to interface with the SARS manifold tubing. The housing is designed to vent return gases (vapors) around the peripheri of the port and, thereby, ensure free flow of fuel.

A removable debris screen prevents the entry of material in excess of 3 mm (1/8 in.), in any dimension, from entering the system through the port.

4.2.1.1.2 Construction

The methods of construction used during fabrication and assembly of the Manual Fill Port includes various types of welding and forming as well as accepted machining processes. The completed assembly will withstand internal pneumatic pressures of not less than .34 MPa (50 PSI) and is water proof. The materials used in construction of the Manual Fill Port are not subject

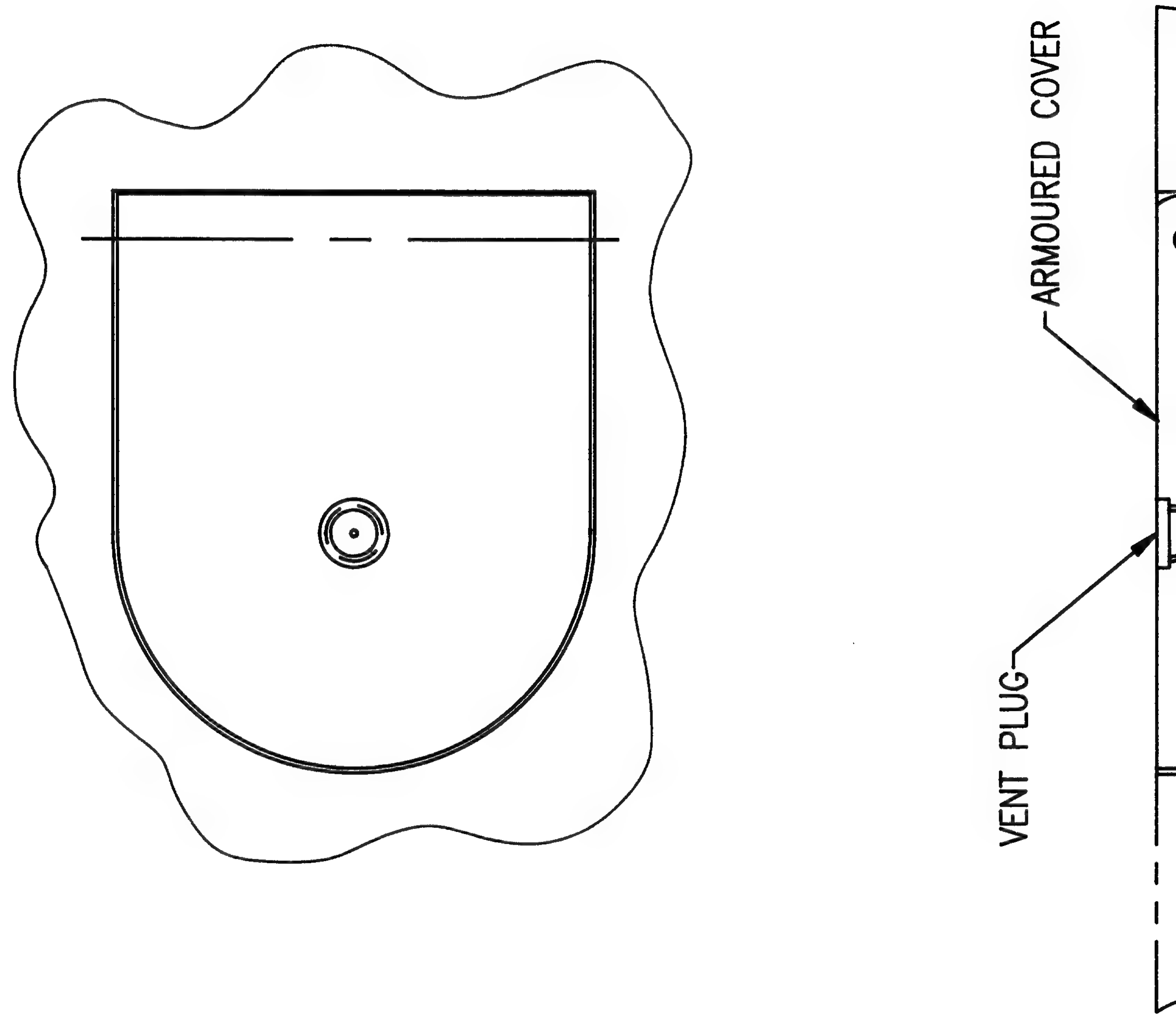
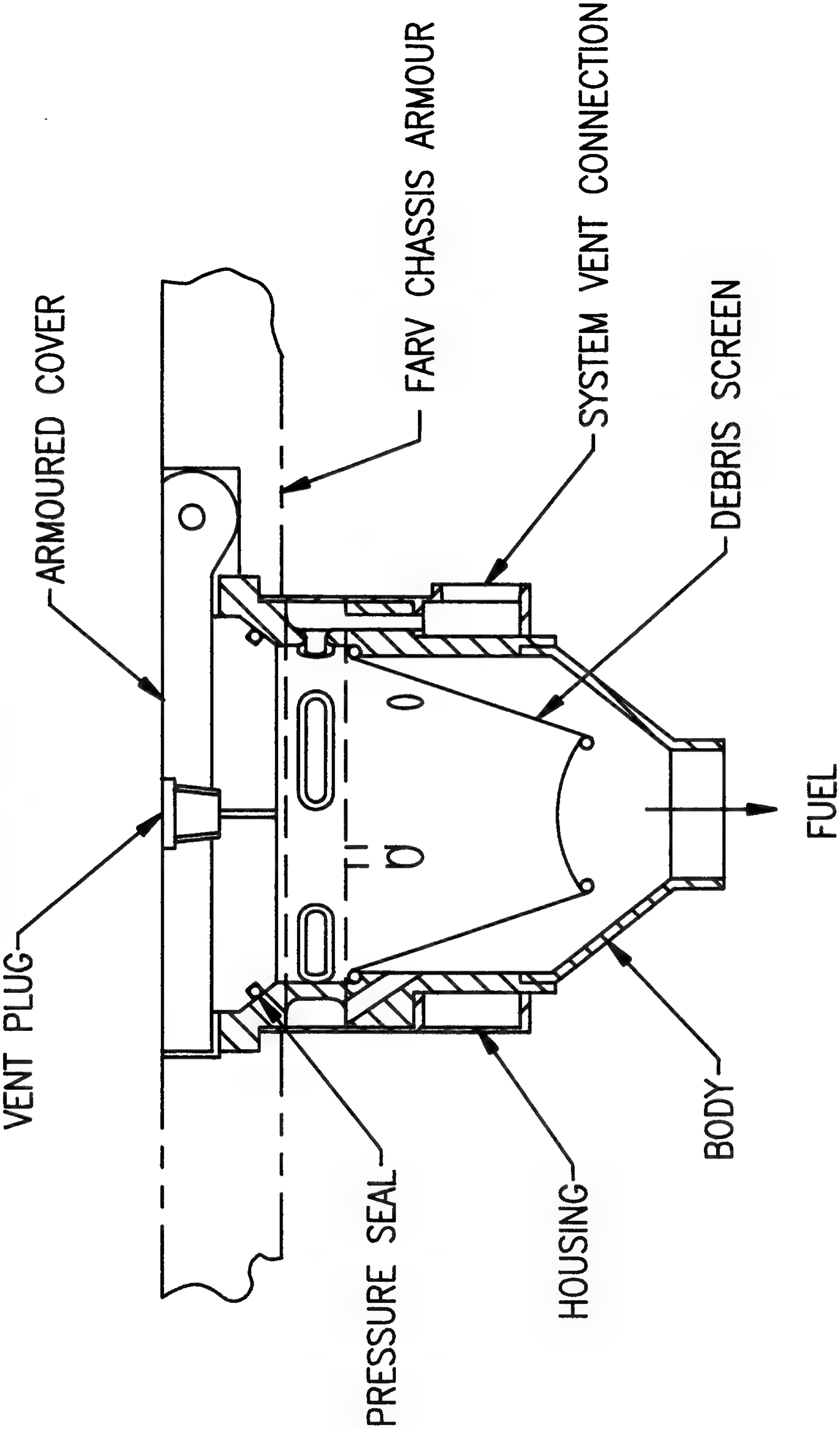


FIGURE 4A. MANUAL FUEL



L FUEL FILL PORT

to corrosion or degradation when exposed to water, petroleum based fuel and chemical contaminant. Exterior surfaces shall be protected by inert coatings that resist degradation when exposed to marine environments and known chemical warfare agents. Seals are replaceable and manufactured from material that does not support combustion.

4.2.1.1.3 Accessibility

The Manual Fill Port is located on the top of the vehicle, centered, and in line with the partition between the crew and munition storage compartments. Personnel using the Manual Fill Port are required to mount the vehicle to access the Port.

4.2.1.2 SARS Receptacle

The SARS Receptacle and housing, coupled to the SARS Manifold and properly designed Saddle (side) and Down (belly) fuel tanks, enable SARS equipped refueling points to upload the FARV in accordance with the time and volumetric requirements of AMC-R 70-17. The SARS Receptacle is the mechanical interface for SARS Refueling/Defueling operations.

4.2.1.2.1 Design and Construction (Ref. Figure 4)

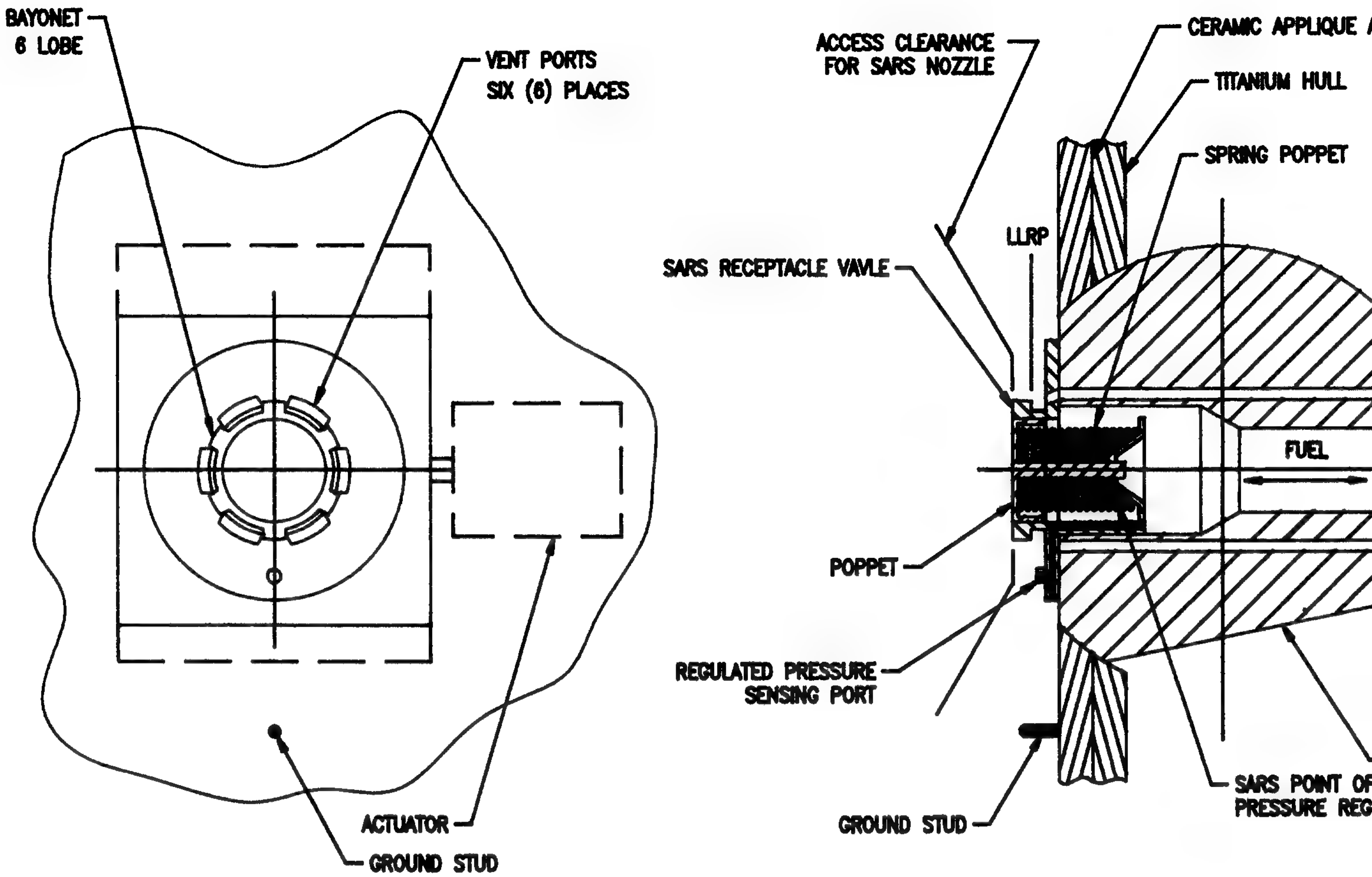
The design and construction of the SARS Receptacle and Receptacle Housing is in accordance with MIL-HDBK-XXXX, Revision C, SARS FUEL SYSTEM DESIGN GUIDE FOR MILITARY REFUELABLE VEHICLES AND GROUND EQUIPMENT, modified as necessary to meet the FARV requirements.

The design of the receptacle housing protects the receptacle when it is not in use. The SARS Receptacle Housing rotates in such a manner as to deny access to the receptacle when it is not in use. The rotatable housing is operated by automated mechanisms controlled from the interior crew space. When the SARS Receptacle is accessible from the exterior of the FARV, a signal shall designate the "open" condition to the EEIM. When closed, the housing is flush with the exterior surface in the immediate area.

The materials used in receptacle and housing fabrication are not subject to corrosion or degradation when exposed to fuels, water, and chemical decontaminant.

4.2.1.2.2 Accessibility

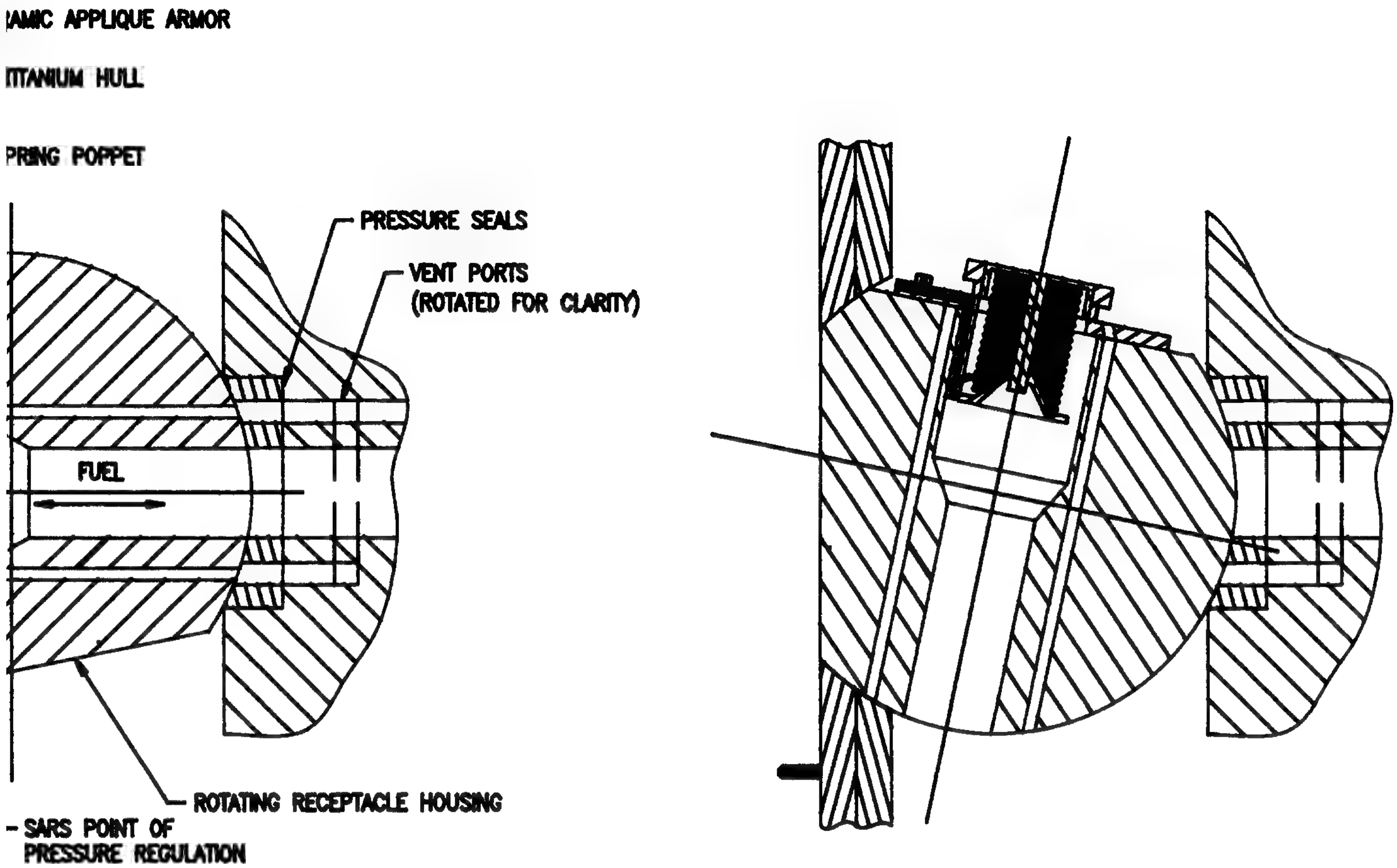
Two SARS Receptacles are incorporated into the



(OPERATIONAL MO

FARV VEHICLE SARS R

FIGURE N



IONAL MODE)

(PROTECTED MODE)

RS RECEPTACLE PORT
RE NO. 4

design of the FARV, one on each side of the chassis. The SARS Receptacle is readily accessible to personnel standing on the ground. The receptacles are located well forward of the engine compartment to ensure against vapor ignition during "hot" refueling.

4.2.1.3 Auto-Receiver

The Auto-Receiver receptacle permits the FARV to be refueled by another FARV in a battlefield environment without personnel leaving the protection of the crew spaces. The receptacle allows the robotic resupply arm of another FARV to dock and up-load fuel and munitions in the same manner that an AFAS receives similar logistic supplies from a FARV. The Auto-Receiver includes componentry necessary to electrically bond the two vehicles prior to transfer of any supplies, as well as communication devices and mechanical interlock components required to ensure safe and rapid transfer of fuel, liquid propellant (LP), and projectiles.

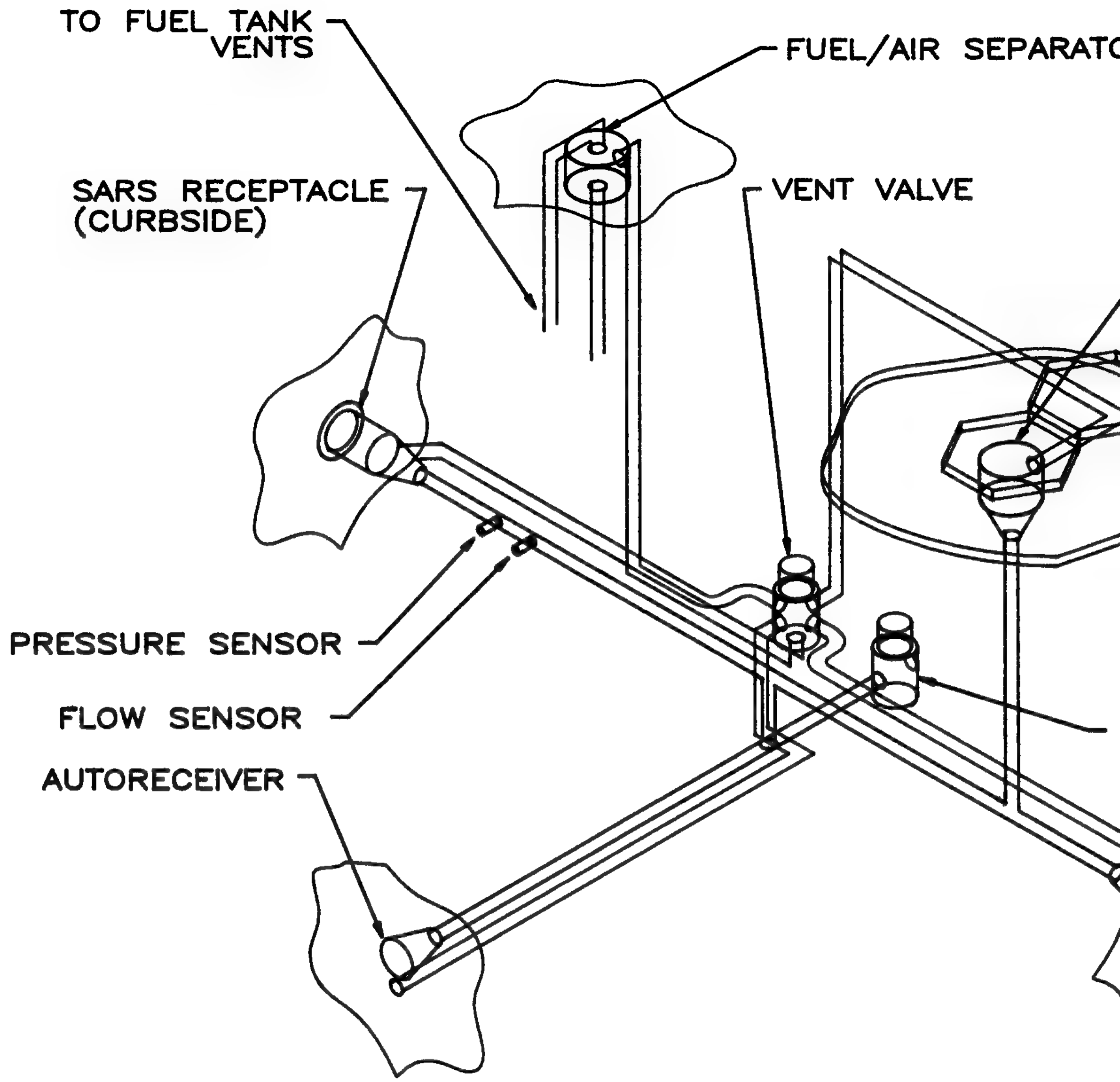
4.2.1.3.1 Design

The Auto-Receiver receptacle integrates a SARS-type fuel receptacle with the components necessary to ensure vehicular bonding, inter-vehicular communication, LP transfer, munitions transfer, and fuel transfer. The components required to mechanically interface with the robotic arm of another FARV are fabricated from non-sparking materials. The design insures mechanical contact of the bonding components prior to any other contact, mechanical or electrical. Electronic communication is confirmed prior to the initiation of mechanical or hydraulic transfer of fuel, LP or projectiles.

The design of the Auto-Receiver incorporates armor that will protect the robotic mechanisms when not docked. The armor shall not impede the transfer of fuel, LP or projectiles nor will it interfere with docking operations.

4.2.2 SARS Manifold (Ref. Figure 5)

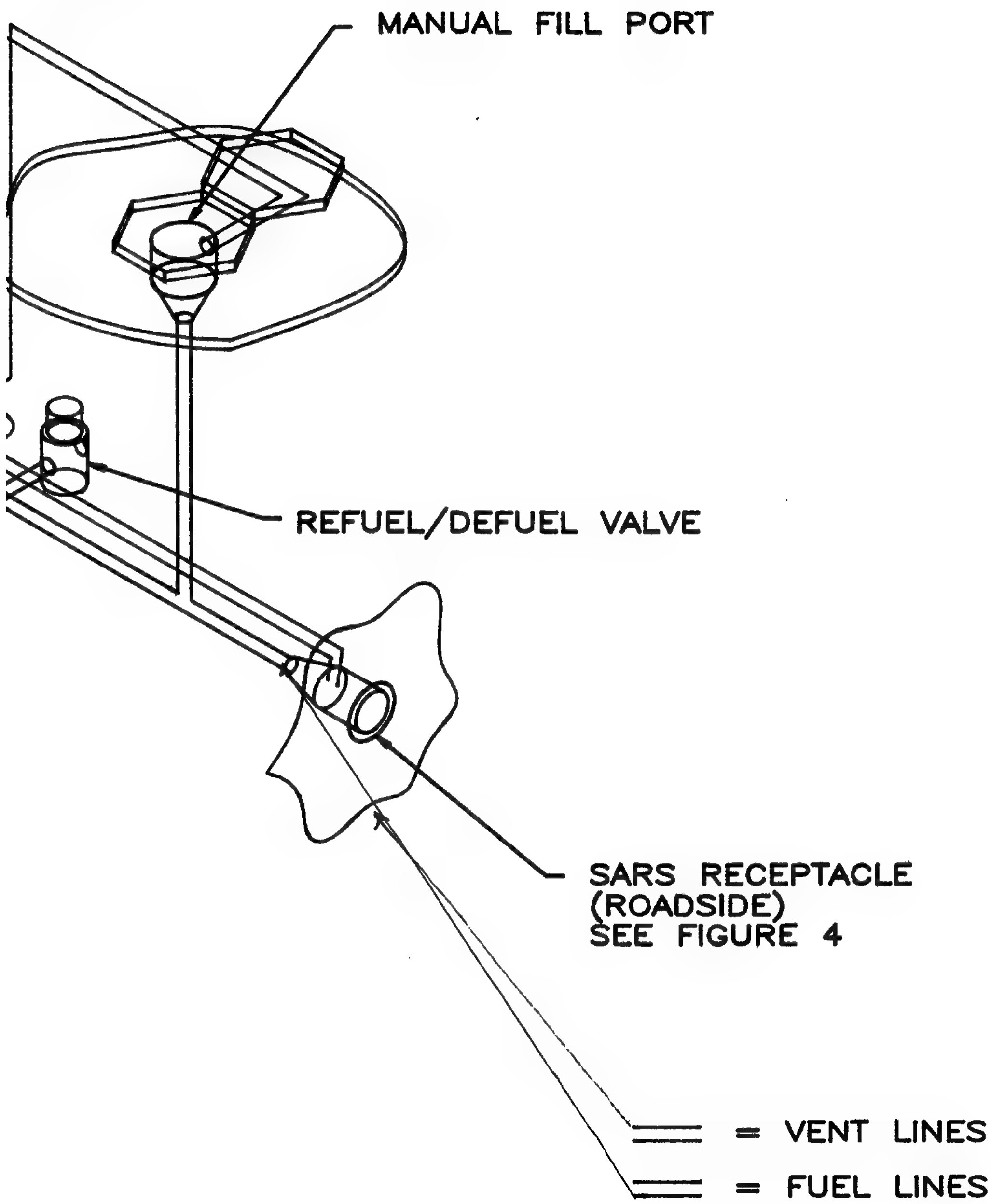
The SARS Manifold connects the roadside and curbside SARS Receptacles, the Manual Fill Port, and the Auto-receiver to the Refuel/Defuel selector valve and terminates at each of the on-board fuel tanks. The manifold is sized to allow fuel flow of not less than 700 LPM (185 GPM) at .12 MPa (18 PSI) in accordance with SARS refueling requirements.



SARS MANIFOLD
FIGURE NO. 5

:L/AIR SEPARATOR

T VALVE



ANIFOLD
NO. 5

)

4.2.2.1 Design

The design of the SARS Manifold does not restrict the flow of fuel to the tanks. Changes in the direction of fuel flow are made using smooth, shallow, turns. Two inch (2") seamless extruded tubing is used in the design of the manifold. The manifold design incorporates flanges for interfacing with tanks and valving, as well as manifoldsections. Connection with receptacles are fluid and air tight. O'Ring seals are used at all points of connection and interface. Threaded bosses are provided for sensor mounting. Elastomeric composite vibration brackets are integrated into the design of the manifold for mounting.

4.2.2.2 Construction

The methods of construction used during fabrication and assembly of the SARS Manifold include welding, forming and casting processes as well as accepted machining practices. The materials used in component fabrication are not subject to corrosion or degradation when exposed to water and petroleum based fuels. Seals are replaceable and manufactured from material that will not support combustion. Seals are not subject to degradation when exposed to marine environments and known chemical warfare agents.

4.2.2.3 Accessibility

The placement of the SARS Manifold within the FARV chassis is dependant upon the positioning of the right and left side SARS Receptacles. Access to the Manifold is gained through panels, or doors, in bulkheads which separate the differing spaces. Only the sensor and valving components integrated into the design of the SARS Manifold are readily accessible.

4.2.3 Fuel Storage

The FARV is capable of safely storing and transporting 1,360 liters (359.3 gallons) of fuel, in a battlefield environment. This is accomplished by the incorporation of three fuel tanks (cells) into the design of the FARV.

4.2.3.1 Down (Belly) Tank

The Down Tank is located within the lower hull of the FARV chassis. The tanks' longest dimension is perpendicular to the longitudinal axis of the vehicle. The tank capacity of the down tank shall be not less than 637 liters (168.3 gallons). The tank is supported within the hull by elastomeric vibration isolating mounts.

4.2.3.1.1 Design

The profile of the Down Tank is appropriate to its placement within the hull of the FARV. The design of the tank allows for a sump with a capacity of approximately 28.4 liters (7.5 gallons) and for ullage space of an equal amount.

Baffling is incorporated into the design of the tank to limit the effect of wave motion, subsequent aeration and surges in pressure. The baffles are perpendicular to the long axis of the tank and extend the full height of the tank. The baffles do not restrict free fuel flow nor allow the accumulation of water, sediment or other contaminates to build-up in an area not accessible for drainage. Separation between baffles is according to accepted commercial practice for tanks and pressure vessels.

The tank incorporates bottom loading and velocity diffusion to lessen sediment agitation and fuel foaming. Two fuel fill tubes are incorporated into the design of the fuel tank to decrease manifold fuel pressure and wave motion within the tank. The bottom loading fuel fill tubes are flange mounted to the top of the tank to reduce the possibility of leakage.

The Transfer Pump scavenging tube (1.5" dia.) picks up fuel 19 mm (3/4 in.) above the bottom of the tank. The bottom of the tank being defined as the point at which the sump cavity starts, in other words, the lowest point at which fuel is to be assumed as uncontaminated by water or particulate matter. The aperture/connection for the suction tube enters the tank from the side of the tank.

The tank incorporates a sump which provides for a 5% sediment/water allowance. The sediment allowance is entirely contained within the confines of a slope sided sump. The sump contains 31.9 liters (8.4 gallons) of volume and is 101.6 mm (4 in.) in depth. The sump shall incorporate a 3/4 inch drain fitting.

The VFM supply and return lines (.75 dia. tubing) pick-up and return fuel at opposite ends of the tank. The supply tube picks up fuel at a level which corresponds to 13 mm (1/2 inch) above the 5% maximum sediment allowance of the sump. The return line deposits fuel in the tank at a level higher than the minimum fuel height.

The tank contains multiple vent apertures which

feed a single vent tube. The total cross section of the vent apertures is not less than the supply tubes cross section. The tank also incorporates an aperture/fitting suitable for safety valve installation.

The tank incorporates a vertical tube at its geometric center. This tube provides the "platform" for housing the fuel level sensors, pressure and temperature devices required to monitor fuel condition. This "Sensor Tube" is flange mounted on the top of the tank.

4.2.3.1.2 Construction

The methods of construction employed during fabrication and assembly of the Down Tank include welding and accepted machining processes applicable to alloy steels. The material used is inherently resistant to corrosion when exposed to water and is not degraded by petrochemical fuels while providing additional ballistic protection. The material is not susceptible to degradation or warpage when exposed to elevated temperatures or extreme cold.

The tank is capable of sustaining an over pressure condition of .034 MPa (5 PSIG) without permanent deformation or leakage.

The interior of the tank is coated with a self sealing elastomeric compound used to seal the tank interior.

The design of the tank integrates elastomeric mounts and bracketry to isolate the tank from drive train vibration and transportation shock.

4.2.3.1.3 Accessibility

The Down Tank is not easily accessed for maintenance or repair. The tank nests in the base of the hull/chassis between the engine and robotics compartments. The Sensor Tube and operational valving are accessed by the removal of panels in partitions and bulkheads.

4.2.3.2 Side (Saddle) Tank(s)

Side, or Saddle, tanks are located within the upper, armored, structure of the FARV, aft of the crew compartment. Each tank is placed longitudinally along, and inside of, the armored exterior of the FARV in order to afford the munitions storage compartment additional ballistic protection. Each tank has a capacity of 428.8 liters (113.3 gallons). Each

tank is supported within the armored munitions storage compartment by elastomeric vibration isolation mounts. The tanks are separated from the munitions by bulkheads.

4.2.3.2.1 Design

The profile of each Saddle Tank is appropriate to its placement within the armored upper chassis of the FARV. The design of each tank incorporates a sump with a capacity of 19 liters (5 gallons) and ullage space of equal capacity.

Each tank is baffled to reduce the effects of wave motion, subsequent fuel aeration and surges in pressure. The baffles are perpendicular to the long axis of the tank and extends the full height of the tank. The baffles do not restrict free flow of fuel nor allow accumulation of water, sediment, or other particulate matter to build-up in an area not accessible for drainage. Separation between baffles is according to accepted commercial practice for tanks and pressure vessels.

The design of the tank incorporates two (2) fill tubes. The fill tubes bottom load the tank and incorporate velocity diffusion to lessen sediment agitation and fuel foaming. The fill tubes are flange mounted to the top of the tank to reduce the probability of leakage.

A 1-1/2 inch diameter suction tube is incorporated into the design of each tank for fuel transfer. The tube picks up fuel from a level 19 mm (3/4 in.) above the bottom of the tank. The bottom of the tank is similar in definition to the Down Tank. The aperture/connection for the suction tube enters the tank from the side.

The sump contains 21.4 liters (5.7 gallons) of volume and is 101.6 mm (4 in.) deep. The sump is slope sided and incorporates a 3/4 in. drain fitting.

The Vehicle supply and return fuel lines (.75 dia. tubing) pick-up and return fuel at the "rear" of the tank. The supply, or suction, tube picks up fuel 13 mm (1/2 in.) above the bottom of the tank.

Vent tubes are incorporated into the tank design at each end of the tank. The total cross section of the vent tube apertures is not less than the total cross-section of the supply tubes. The tank design includes an aperture/connection for a pressure (safety) blow-off

valve.

The tank incorporates a vertical tubular housing at its geometric center. This tubular housing provides a "platform" for mounting the fuel level sensors, pressure and temperature devices required to monitor fuel condition. This "Sensor Tube" is flange mounted to the top of the tank.

4.2.3.2.2 Construction

The methods of construction employed during fabrication and assembly of the Saddle Tanks includes welding and accepted forming and machining processes applicable to alloy steels. The materials used in fabrication are inherently corrosion resistant and do not degrade when subjected to petrochemical fuels while providing additional ballistic protection. The material is not subject to degradation and/or warpage when exposed to elevated temperatures and extreme cold.

The tank is capable of withstanding an overpressure condition of not more than .034 MPa (5 PSIG) without permanent deformation or leakage.

The tank interior surfaces are also coated with a self-sealing elastomeric compound to resist and seal small punctures and leaks.

The tank is isolated from drive train vibration by elastomeric mounts and bracketry.

4.2.3.2.3 Accessibility

The accessibility of the Saddle Tanks is dependent upon the design and placement of the armor on the FARV chassis. The tanks are positioned between the exterior armor and the storage and conveyance componentry required by the projectiles. Accessibility from the munitions compartment is limited to that required for repair and maintenance of the valving and sensors. All access requires the removal of panels or partitions specifically designed for the purpose.

4.2.3.3 Tank Heater(s)

Tank heaters are installed in the sump cavity at the bottom of each tank to ensure that sump and drain valve temperatures are maintained above the freezing point of water. The heating elements are explosion proof. Each Tank heater is powered by AC voltage produced by an inverter. Each inverter is located in close proximity to the heater.

An inverter is required for each Tank heater.

4.2.3.3.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Type:	Immersion/Screw Plug
Watts:	300
Voltage:	120 VAC
Phase:	Single
Hertz:	50/60
Material:	Stainless steel sheath
Thread:	3/4 NPT

4.2.3.3.2 Accessibility

The heaters and inverters are located at the base of each tank. Access can only be accomplished by the removal of panels and covers specifically designed for the purpose. The heaters are not repairable, only replaceable.

4.2.4 Controls

Mechanical control devices are required to limit the amount of fuel in each tank and to ensure the required ullage in each tank is maintained when filled. FSM control requirements necessitate the use of solenoid and motor operated valves to limit, select and/or divert fluid and gaseous flow. Valve and control choice was based on the components compatibility with electrical/electronic actuation and control, speed of operation, application history and materials of manufacture.

4.2.4.1 Diverter Valve, Vent (V11)

The vent diverter valve is an electrically operated valve which directs the vent flow from the fuel storage tanks to the receptacle that is supplying fuel to the FARV during refueling, or to the manual fill port during normal operation and transport.

4.2.4.1.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Linear control, ball

Max operating temp:	100°C (212°F)
Valve operation method:	Electric motor
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Flanged
No. of connections:	4
Valve size:	2 in.
Weight [Kilograms (Kg) (Pounds (Lbs))]:	18.1 (40)
Size [mm (in.)]	177.8W X 203.2L X 355.6H (7W X 8L X 14H)

4.2.4.2 Selector Valve, Vent (V10)

The vent selector valve is an electrically operated valve which permits either the vent manifold to supply air, displaced from another vehicle during refueling, to the FARV fuel tanks or vent gases to enter the fuel/air separator.

4.2.4.2.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Linear control, ball
Max operating temp:	100°C (212°F)
Valve operation method:	Electric motor
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Flanged
No. of connections:	3
Valve size:	2 in.
Weight [Kg (lbs)]:	18.1 (40)
Size [mm (in.)]:	177.8W X 203.2L X 355.6H (7W X 8L X 14H)

4.2.4.3 Ball Shut-Off Valve, Tank Supply (V2)

The fuel supply lines to each tank include an electrically operated ball valve to control the amount of fuel entering the tanks. The valve shall work in conjunction with sensors to maintain the required ullage during refueling operations.

4.2.4.3.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Ball valve
Max operating temp:	100°C (212°F)
Valve operation method:	Electric Solenoid
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Flanged
No. of connections:	2
Valve size:	2 in.
Weight [Kg (lbs)]:	18.1 (40)
Size [mm (in.)]:	152.4W X 177.8L X 355.6H (6W X 7L X 14H)

4.2.4.4 Ball Valve, Tank Drain (V12)

The sump of each fuel storage tank has an electrically operated ball valve in the tank drain line to allow drainage of contaminants (water/sediment) when activated by a crew member.

4.2.4.4.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Ball valve
Max operating temp:	100°C (212°F)
Valve operation method:	Electric Solenoid
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Internal threaded
No. of connections:	2
Valve size:	3/4 in.
Weight [Kg(lbs)]:	9.1 (20)
Size [mm(in.)]:	101.6W X 101.6L X 279.4H (4W X 4L X 11H)

4.2.4.5 Valve, Refuel/Defuel (V1)

The Refuel/Defuel Valve is an electrically operated valve which, during refueling, directs incoming fuel to the storage tanks or during defueling of another vehicle it will allow the fuel transfer pump to be used to siphon fuel through any of the inlet ports.

4.2.4.5.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Linear control
Max operating temp:	100°C (212°F)
Valve operation method:	Electric motor
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Flanged
No. of connections:	3
Valve size:	2 in.
Weight [Kg (lbs)]:	18.1 (40)
Size [mm (in.)]:	177.8W X 203.2L X 355.6H (7W X 8L X 14H)

4.2.5 Venting

The Fuel Storage Module is an atmospheric pressure system. In order to receive, use, transfer and off-load fuel, the system, and each tank, must be vented. The venting components must be capable of allowing the maximum amount of air and vapor to be displaced without restrictions which impede fuel movement by causing backpressure. The maximum volume of displaced air is approximately 680 LPM (41,500 cubic inches per minute).

During refueling operations the vent gases are directed to the same port that is being used to up-load or down-load the vehicle. When the FARV is being refueled by SARS Receptacle and by the Auto-Receiver, a vacuum is provided to expedite the operation. When being refueled by the Manual Fill Port, fuel displaces the air/vapors and they escape through the large fill port aperture.

4.2.5.1 Fuel/Air Separator

A Fuel/Air separator is incorporated into the design of the FSM. The separator allows fuel entrained in the vent air flow to drop out and be caught for return to the fuel storage tanks. The unit uses centrifugal force to drive fuel from the flow of air.

4.2.5.1.1 Design

The Fuel/Air Separator is sized for the free passage of 680 liters (24.02 cubic feet) of air per minute. Vent tubing from each of the tanks discharges air tangent to, and at the top of, the housing of the separator. Any fuel entrained in the air is precipitated centrifugally around the interior of the separator. Air exits the separator through the top of the housing while fuel drops to the bottom of the unit until it is drained back into the storage tanks.

The conical base of the unit incorporates a drain to which an automatic valve is attached.

The design of the separator negates the need for routine maintenance.

The unit is electrically grounded against the build-up of a static electricity charge

The assembled unit withstands pressures from -.017 to +.34 MPa (-2.5 PSIG to +50 PSIG).

4.2.5.1.2 Construction

The methods of construction employed during fabrication and assembly of the Fuel/Air Separator include welding, forming and accepted machining processes applicable to corrosion resistant materials. The material from which the separator is fabricated is not degraded by exposure to water or petroleum based fuels. The materials from which the unit is constructed is not susceptible to degradation or warpage when exposed to elevated temperatures and/or extreme cold.

4.2.5.1.3 Accessibility

The Fuel/Air Separator requires no maintenance and only major system damage would require its' replacement, therefore, accessibility is not required at the unit level.

4.2.5.2 Vent Manifold

The Vent Manifold connects the three fuel storage tanks to the Fuel/Air Separator and terminates at the fueling receptacles. A Vent Diverter Valve and a Vent Selector Valve are included in the path. The Vent manifold insures that the air and fuel vapor that is displaced while refueling is directed properly for recovery.

4.2.5.2.1 Design and Construction

The design of the Vent Manifold does not impede the flow of air/vapor from the storage tanks through the separator to the appropriate receptacle. Changes in direction are made smoothly, with little or no purturbances or irregularities in the pathway. Appropriately sized, corrosion resistant, seamless, tubing is used in the design and construction of the manifold. The manifold design incorporates flanges for interfacing with valving, the fuel/air separator, tanks and receptacles as well as between manifold tubing sections. O'Ring seals/gaskets are incorporated at all connection points.

The methods of construction employed during fabrication and assembly of the manifold include welding and forming as well as accepted machining processes applicable to corrosion resistant alloys. The materials used are not subject to degradation when exposed to water and petrochemical fuels as well as elevated temperatures and extreme cold. Seals are replaceable and manufactured from material not subject to degradation when exposed to marine environments and known chemical warfare agents.

4.2.5.2.2 Accessibility

The placement of the Vent Manifold within the FARV chassis is dependant upon the positioning of the SARS Manifold. With the exception of the Fuel/Air Separator, the two manifolds are positioned in close proximity to one another for most of their length. Access to the manifold is gained, where necessary to access valves, through panels or doors in bulkheads which separate the differing spaces of the FARV.

4.3 VEHICLE FUEL MODULE (Ref. Figure 6 and 8)

The VFM integrates fabricated and COTS components that route and condition fuel for on-board internal combustion engine use. The VFM supplies fuel to the FARV MPU and APS.

4.3.1 Fuel Recirculation

Fuel is required by the MPU and the APS. The fuel usage may be by either of the units or by both at the same time. The loads on both units vary from idling, under no load, to full power, at full load. The fuel consumption rates and pressures vary proportionately.

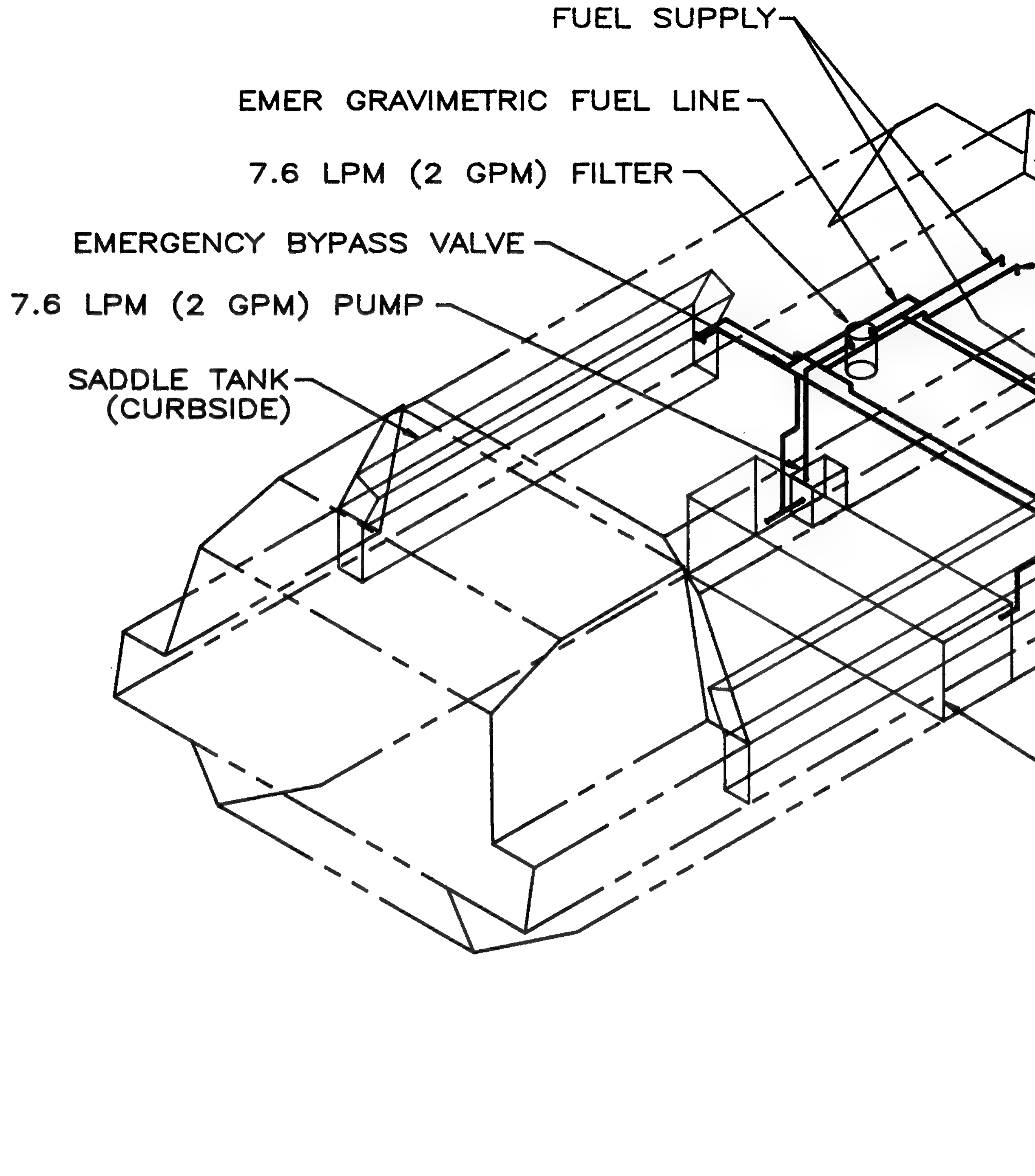
Fuel is provided at the maximum consumption rate plus 20%. Excess fuel not used by the units bypasses the engine fuel intake and is returned to a fuel storage tank.

4.3.1.1 Pump and Motor

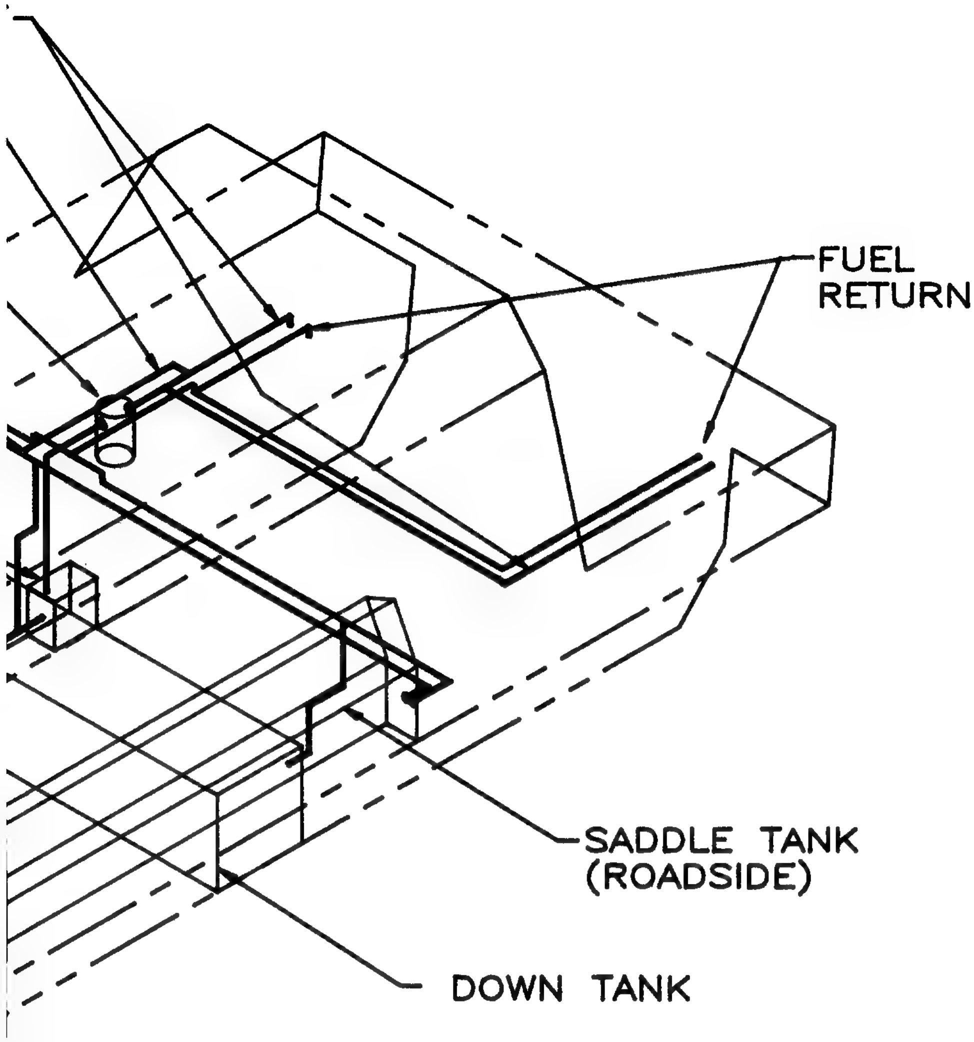
The VFM fuel pump and motor assembly provide a constant fuel flow to the MPU and APS.

4.3.1.1.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:



VEHICLE FUEL M
FIGURE 6



= FUEL RETURN
= FUEL SUPPLY
= FUEL TANKS

FUEL MODULE
GURE 6

Pump capacity:	7.6 LPM (2 GPM)
Delivery pressure:	.52-.69 MPa (75-100 PSI)
Self-priming	
Opererating temperature range:	-49°C to 52°C (-54.4°F to 125.6°F)
Withstand hydrostatic pressure of .55 MPa (80 PSI)	
Port size:	3/4 in.
Motor power rating:	1/3 Horsepower (HP)
Motor Voltage:	24 VDC
Rotor speed in Revolutions Per Minute (RPM):	3500 RPM max
Duty cycle:	Continuous
Inclosure features:	Totally enclosed, fan cooled, NEMA class 1, group D explosion-proof
Sealed bearings	
Weight [Kg(lbs)]:	15.9 (35)
Size [mm(in.)]:	101.6W X 279.4L X 177.8H (4W X 11L X 8H)

4.3.1.1.2 Accessibility

The VFM fuel pump and motor assembly is accessible through the engine compartment. Fuel line suction and pressure connections are self-seal, quick disconnect flexible hose connections for ease of repair and replacement.

4.3.2 Fuel Conditioning

Fuel used by the FARV for propulsion and to generate power is stored for an undeterminable time in the on-board fuel tanks. Battlefield conditions often do not guarantee the condition of fuels. The possibilities exist that the fuel stored in the on-board tanks may contain emulsified or stratified water, sediment and/or other particulate deleterious to the operation of the MPU and APS. Fuel conditioning is required to ensure that the fuel supplied to the FARV MPU and APS is free of contaminants.

4.3.2.1 Fuel Filter/Separator

The VFM Fuel Filter/Separator conditions the fuel by removing suspended particulate matter and emulsified water from the fuel prior to its use.

4.3.2.1.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS

component:

Capacity:	7.6 LPM (2 GPM)
Filter elements to remove particles to 10 microns	
Drain for removal of water from housing	
Provision for water sensor module	
Fluid bypass	
Filter housing and seal materials shall not be degraded by contact with fuel, water or chemical decontaminant	
Weight [Kg(lbs)]:	4.5 (10)
Size [mm(in.)]:	177.8 Diameter (DIA) X 584.2H (7 DIA X 23H)

4.3.2.1.2 Accessibility

The VFM Fuel Filter/Separator is accessible through the engine compartment. Fuel line connections are the self-sealing, quick disconnect, type for ease of repair and replacement.

4.3.2.2 Filter/Separator Drain Valve (V14)

The Filter/Separator Drain Valve is an electrically operated ball valve that permits automated removal of collected water from the separator housing.

4.3.2.2.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Ball valve
Max operating temp:	150°C (300°F)
Valve operation method:	Electric Solenoid
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Internal threaded
No. of connections:	2
Valve size:	3/4 in.
Weight [Kg (lbs)]:	1.36 (3)
Size [mm (in.)]:	50.8W X 76.2L X 101.6H (2W X 3L X 4H)

4.3.2.2.2 Accessibility

The Filter/Separator Drain Valve is accessible through the engine compartment.

4.3.3 Fuel Flow Control

4.3.3.1 Tank Selector Valve, Supply (V6)

The Tank Selector Valve is an electrically operated directional control valve used to select the tank from which fuel is supplied to the FARV MPU and/or APS.

4.3.3.1.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Linear control
Max operating temp:	150°C (300°F)
Valve operation method:	Electric motor
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Internal threaded
No. of connections:	4
Valve size:	3/4 in.
Weight [Kg (lbs)]:	11.3 (25)
Size [mm (in.)]:	101.6W X 101.6L X 279.4H (4W X 4L X 11H)

4.3.3.2 Tank Selector Valve, Return (V7)

The return line tank selector valve is an electrically operated directional control valve used to select the tank to which unused fuel from the FARV MPU and/or APS is returned.

4.3.3.2.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Linear control
Max operating temp:	150°C (300°F)
Valve operation method:	Electric motor
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Internal threaded
No. of connections:	4
Valve size:	3/4 in.
Weight [Kg (lbs)]:	11.3 (25)
Size [mm (in.)]:	101.6W X 101.6L X 279.4H (4W X 4L X 11H)

4.3.3.3 Directional Valve, Supply (V8)

The supply line directional control valve is an electrically operated valve used to direct the fuel flow to either the FARV MPU, the APS, or both.

4.3.3.3.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Linear control
Max operating temp:	150°C (300°F)
Valve operation method:	Electric motor
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Internal threaded
No. of connections:	3
Valve size:	3/4 in.
Weight [Kg (lbs)]:	11.3 (25)
Size [mm (in.)]:	101.6W X 101.6L X 279.4H (4W X 4L X 11H)

4.3.3.4 Directional Valve, Return (V9)

The return line directional control valve is an electrically operated directional control valve used to accept unused fuel from either the MPU, the APS, or both and return it to the fuel storage tanks.

4.3.3.4.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Linear control
Max operating temp:	150°C (300°F)
Valve operation method:	Electric motor
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Internal threaded
No. of connections:	3
Valve size:	3/4 in.
Weight [Kg (lbs)]:	11.3 (25)
Size [mm (in.)]:	101.6W X 101.6L X 279.4H (4W X 4L X 11H)

4.4 FUEL TRANSFER MODULE (Ref. Figure 7 and 8)

The FTM incorporates fabricated and COTS components necessary to condition and off-load fuel to an AFAS or another FARV via robotic means. The module also includes the equipment required to manually refuel other combat and logistic supply vehicles.

4.4.1 Fuel Transfer

4.4.1.1 Fuel Transfer Pump and Motor

The primary function of the Fuel Transfer Pump is to transfer fuel from the fuel storage tanks to the AFAS or another FARV. Valves on either side of the pump also allow the pump to defuel other vehicles or transship fuel from one fuel storage tank to another.

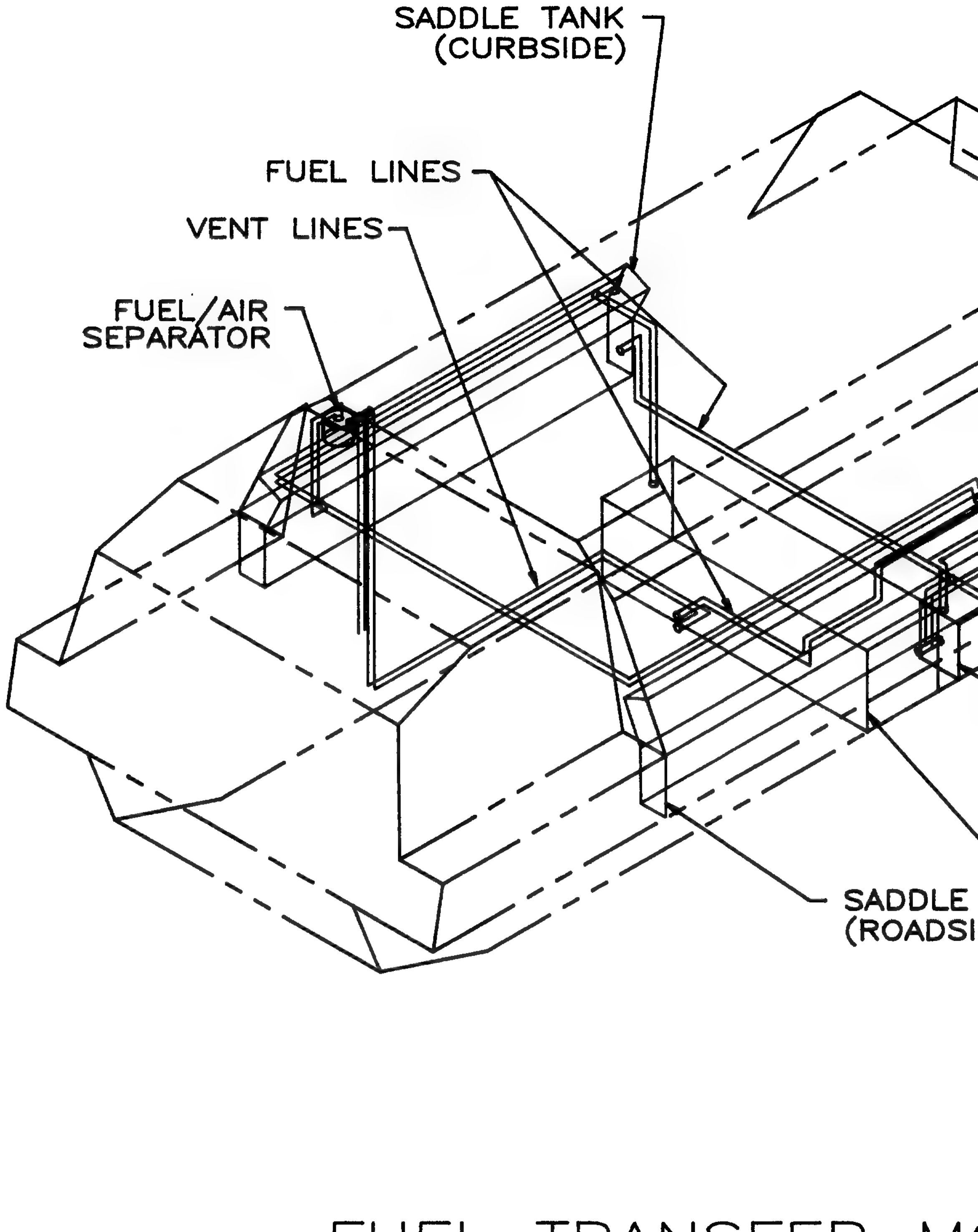
4.4.1.1.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

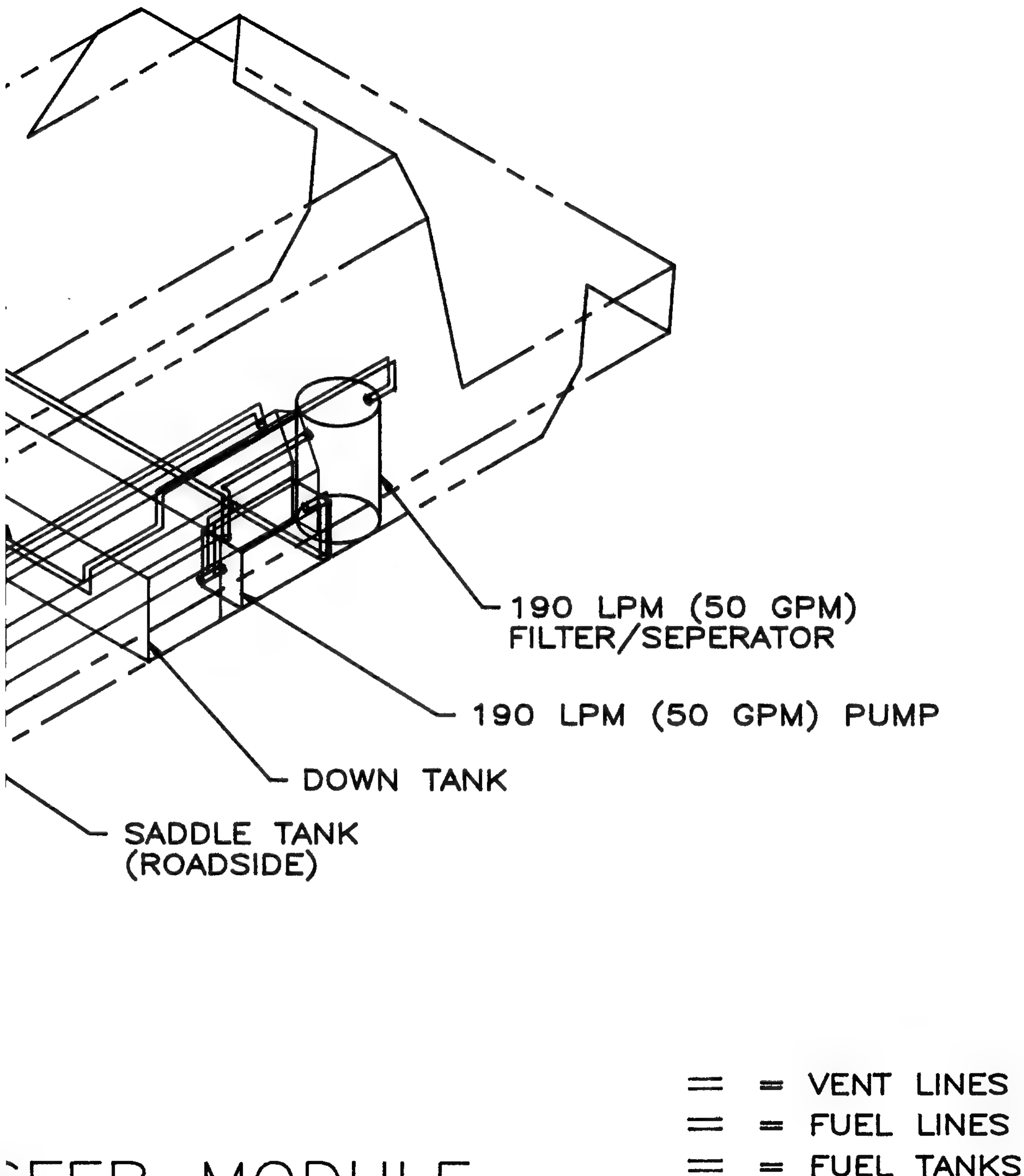
Pump capacity:	132.5-189.3 LPM (35-50 GPM) @ 100 ft head
Delivery pressure:	.12 MPa (18 PSI)
Self-priming	
Operating temperature range:	-48°C to 52°C (-54.4°F to 125.6°F)
Withstand hydrostatic pressure of .55 MPa (80 PSI)	
Port size:	2 in.
Motor power rating:	2 HP
Motor Voltage:	24 VDC
Rotor speed in RPM:	4000 RPM max
Duty cycle:	Continuous
Inclosure features:	Totally enclosed, fan cooled, NEMA class 1, group D explosion-proof
Sealed bearings	
Weight [Kg (lbs)]:	27.2 (60)
Size [mm (in.)]:	304.8W X 685.8L X 381H (12W X 27L X 15H)

4.4.1.1.2 Accessibility

The FTM Fuel Pump Assembly is positioned in the base of the FARV chassis. The pump is behind the Down Tank and below the automated fuse handling mechanism and is not readily accessible for unit level maintenance.



FUEL TRANSFER MO
FIGURE 7



SFER MODULE
RE 7

The unit is designed for removal and replacement as an assembly. The full logistic supply load must be off-loaded to permit access to the assembly. The pump motor assembly requires no preventative maintenance and has a MTBF of more than 10,000 hours.

4.4.2 Fuel Conditioning

4.4.2.1 Filter/Separator

The FTM Fuel Filter/Separator conditions the fuel by removing suspended particulate matter and emulsified water from the fuel prior to transfer to the AFAS or another FARV.

4.4.2.1.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Capacity:	132.5-189.3 LPM (35-50 GPM)
Strainer for large particle removal	
Primary filter:	Replaceable element(s), remove particles to 25-30 microns
Secondary filter:	Replaceable elements, remove particles to 10 microns
Capable of removing emulsified water up to 5% by volume	
Provision for water sensor module	
Drain for removal of water from housing	
Materials:	Filter/separator materials shall not be degraded by contact with fuel, water or chemical decontaminant
Weight [Kg (lbs)]:	61.3 (135)
Size [mm (in.)]:	457.2 DIA X 787.4H (18 DIA X 31H)

4.4.2.1.2 Accessibility

The FTM Fuel Filter/Separator is accessible for replacement of the filter element at predetermined intervals or as indicated by the MMCS. Armored access panels must be removed to gain access to the Filter/Separator cover.

4.4.2.2 Valve, Filter/Separator Drain (V15)

The Filter/Separator Drain Valve is an electrically operated ball valve which permits drainage of collected water from the Filter/Separator housing.

4.4.2.2.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Linear control
Max operating temp:	100°C (212°F)
Valve operation method:	Electric Solenoid
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Internal threaded
No. of connections:	2
Valve size:	3/4 in.
Weight [Kg (lbs)]:	1.36 (3)
Size [mm (in.)]:	50.8W X 76.2L X 101.6H (2W X 3L X 4H)

4.4.3 Controls

4.4.3.1 Ball Valve, Tank Transfer (V3)

The Tank Transfer Valve is an electrically operated ball valve in each of the fuel storage tanks' outlet lines that provides the means of controlling which tank is used to supply fuel to the FTM Pump.

4.4.3.1.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Ball valve
Max operating temp:	100°C (212°F)
Valve operation method:	Electric Solenoid
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Flanged
No. of connections:	2
Valve size:	2 in.
Weight [Kg (lbs)]:	18.1 (40)
Size [mm (in.)]:	152.4W X 177.8L X 355.6H (6W X 7L X 14H)

4.4.3.2 Valve, Pump Inlet (V4)

The Pump Inlet Valve is an electrically operated directional control valve which permits the pump to draw fuel from either the on-board fuel tanks or from an overboard source.

4.4.3.2.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Linear control
Max operating temp:	100°C (212°F)
Valve operation method:	Electric motor
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Flanged
No. of connections:	3
Valve size:	2 in.
Weight [Kg (lbs)]:	18.1 (40)
Size [mm (in.)]:	152.4W X 177.8L X 355.6H (6W X 7L X 14H)

4.4.3.3 Valve, Pump Outlet (V5)

The Pump Outlet Valve is an electrically operated directional control valve which, along with the Fuel Transshipment Valve, enables the FARV to transfer fuel from one fuel tank to another, as well as transfer fuel overboard via the robotics or manual nozzle and hose reel.

4.4.3.3.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Linear control
Max operating temp:	100°C (212°F)
Valve operation method:	Electric motor
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Flanged
No. of connections:	3
Valve size:	2 in.
Weight [Kg (lbs)]:	18.1 (40)
Size [mm (in.)]:	152.4W X 177.8L X 355.6H (6W X 7L X 14H)

4.4.3.4 Valve, Fuel Transshipment (V13)

The Fuel Transshipment Valve is an electrically operated directional control valve which, along with the Pump Outlet valve, enables the FARV to transfer fuel from one fuel tank to another and overboard via the SARS Receptacles.

4.4.3.4.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Linear control
Max operating temp:	100°C (212°F)
Valve operation method:	Electric motor
Max operating pressure:	1.73 MPa (250 PSI)
Voltage/current type:	24 VDC
Connection type:	Flanged
No. of connections:	3
Valve size:	2 in.
Weight [Kg (lbs)]:	18.1 (40)
Size [mm (in.)]:1	52.4W X 177.8L X 355.6H (6W X 7L X 14H)

4.4.3.5 Globe Valve, Manual

The Manual Globe Valve provides the means for manual transfer of fuel to other vehicles via the hose reel and nozzle.

4.4.3.5.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Valve type:	Linear control, globe
Max operating temp:	100°C (212°F)
Valve operation method:	Manual
Max operating pressure:	1.73 MPa (250 PSI)
Connection type:	Flanged
No. of connections:	2
Valve size:	1-1/2 in.
Weight [Kg (lbs)]:	9.1 (20)
Size [mm (in.)]:	127W X 152.4L X 279.4H (5W X 6L X 11H)

4.4.3.5.2 Accessibility

The Manual Globe Valve is accessed by the removal of an armored and hinged cover on the vehicle exterior.

4.4.4 Hose Reel and Nozzle Assembly

The Hose Reel and Nozzle Assembly permits the manual transfer of fuel to other vehicles in unusual circumstances.

4.4.4.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

- Reel
  - Heavy duty spring rewind
  - Intermediate positive stop
  - Roller style fairlead
  - Capacity - 15.2 meters (50 ft) of 1 in. hose
- Nozzle
  - Automatic shutoff
  - 13/16 in. dia nozzle
  - 1 in. female NPT inlet
- Hose
  - Oil and gasoline resistant
  - Textile reinforced
  - Equipped with 1 in. male and female NPT connectors

4.4.4.2 Accessibility (Vulnerability)

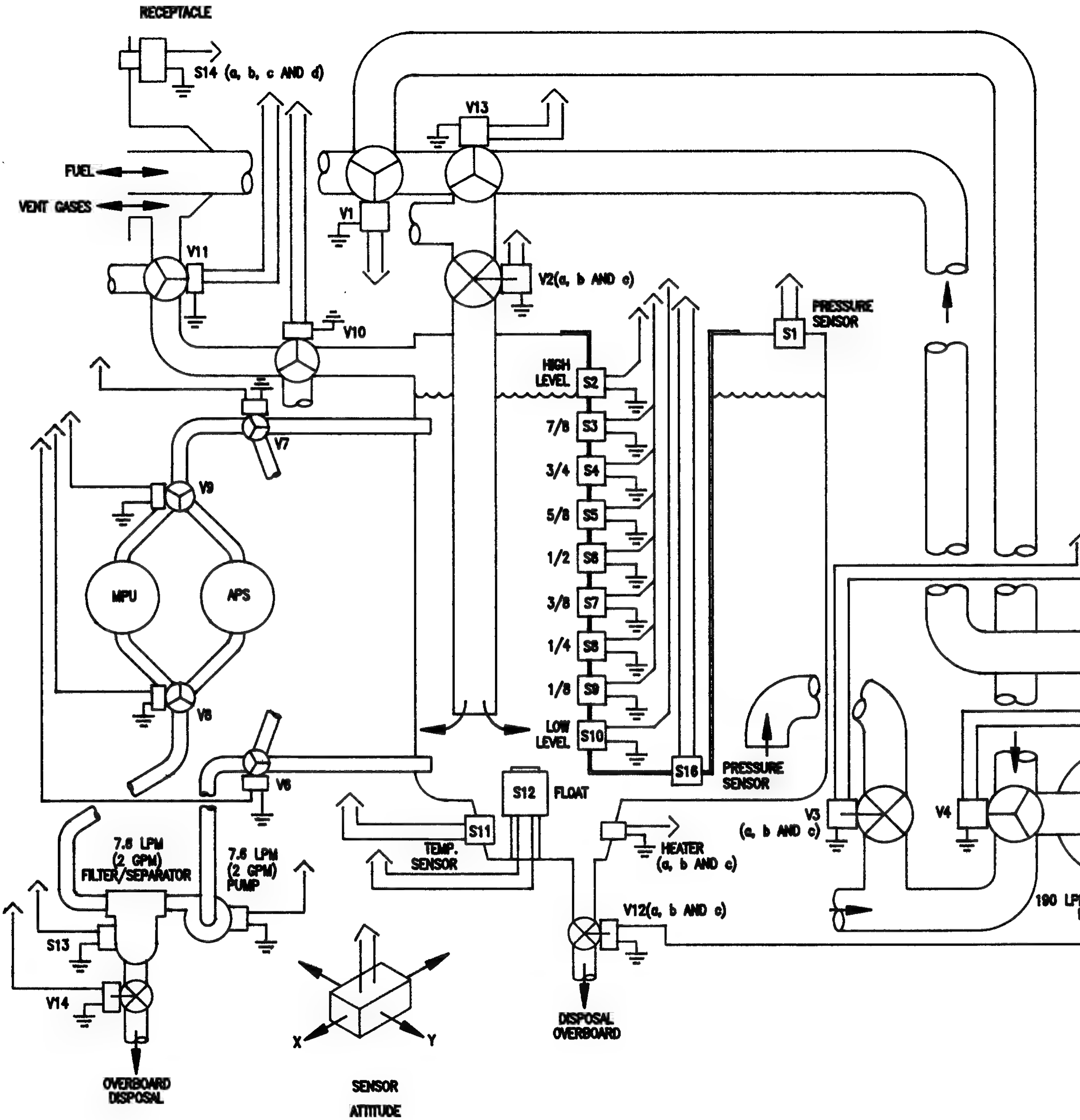
The Hose Reel and Nozzle Assembly is considered expendable and is mounted on the side of the vehicle in an enclosure. The assembly occupies approximately 5 1/2 square feet and weighs approximately 58 lbs. The housing is not armored. The assembly is readily accessible for service and maintenance since dismounted personnel must use it to refuel combat vehicles not equipped with SARS. The fuel line connection is armored and quick disconnect in case of combat loss.

4.4.5 Rotary Union

The rotary union is the interface between the FARV Fuel System and the robotic arm. The union permits the articulated motion required by the arm.

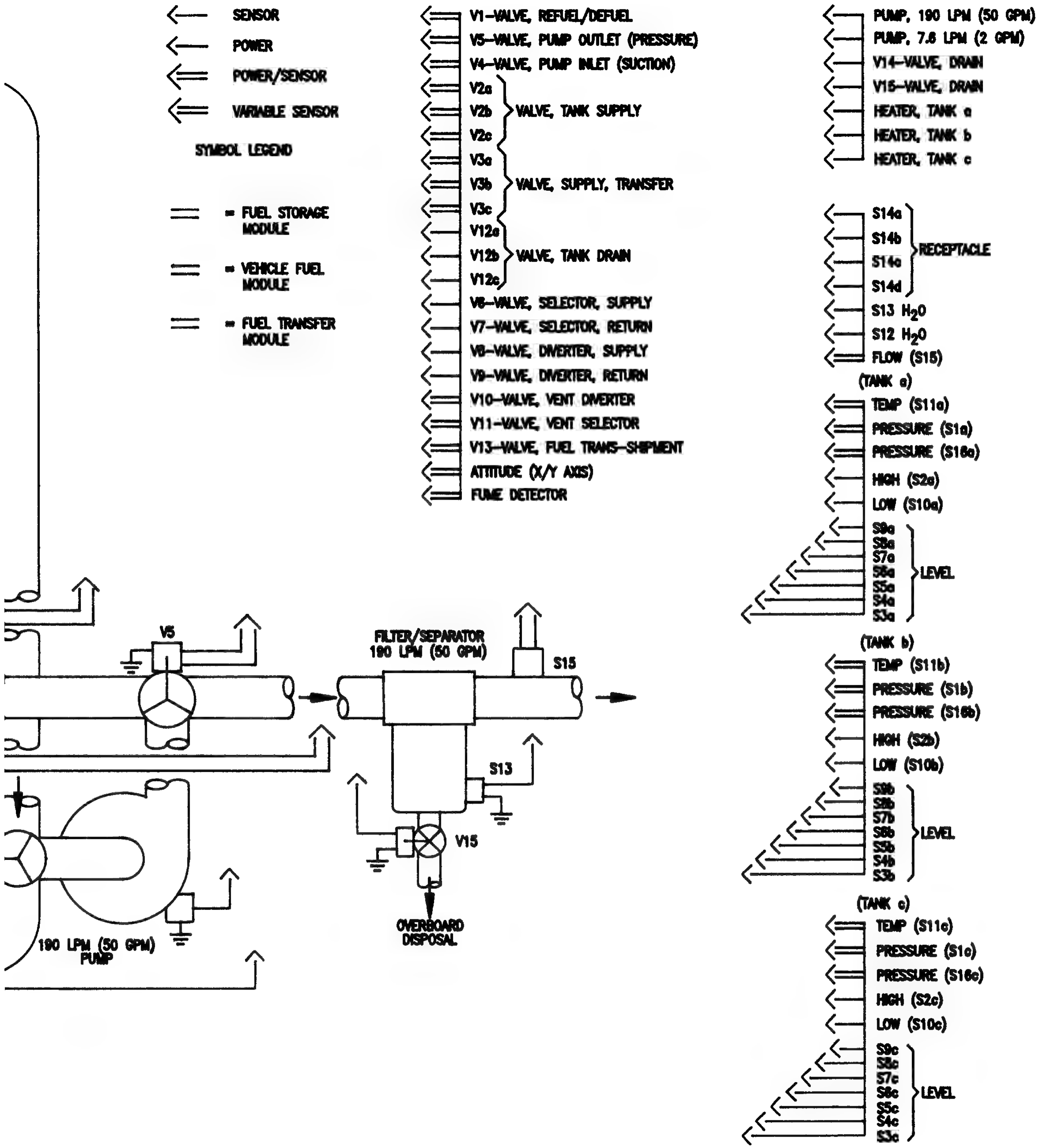
4.5 ELECTRONIC/ELECTRICAL INTERFACE MODULE (Ref. Figure 8)

The EEIM incorporates custom designed and commercially available components required to initiate/terminate and monitor the actions/



FARV FUEL SYSTEM CONTR

FIGURE NO. 8



NTROLS AND SENSORS

). 8

activities of the FSM, VFM and the FTM. The EEIM monitors fluid levels, sediment level, hydraulic and pneumatic pressures, fuel flow, fuel temperature, valve status (position), filter status, vehicle attitude, fuel leaks and access closure. The EEIM responds to directives regarding fuel system operation from the MMCS, thereby permitting the MMCS to direct and control the independent activities of the robotics, communication, navigation, logistics and housekeeping.

4.5.1 Sensors

4.5.1.1 Liquid Level Sensor (high and low) (S2, S10)

The Liquid Level Sensor is a solid state optical device used to indicate the level of fuel in each of the Fuel Storage Tanks. The sensor is mounted in the Sensor Tube.

4.5.1.1.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Solid State Optical Device	with Controller
Input Voltage:	24 VDC
Operating Temp:	-20° to 86°C (-4° to 186.8°F)
Current Consumption:	25 mA
Output:	TTL/CMOS compatible, may sink 40 mA up to 30 VDC
Controller Input:	12 VDC, 160 mA
Controller Output, (Switched):	500 mA max
Sensor Mounting Method:	NPT threaded housing
Weight [Kg (lbs)]:	.45 (1) (sensor w/leads) .91 (2) (controller)
Size [mm (in.)]:	44.4L X 17.5 dia (1.25L X .69 dia) (sensor) 101.6L X 127W X63.5H (4.00L X 5.00W X 2.50H) (controller)
Electrical Connection (Controller):	Screw Terminals

4.5.1.2 Liquid Level Sensor (optical) (S3 thru S9)

The Liquid Level Sensor is a solid state optical device used to indicate the level of fuel in each of the Fuel Storage Tanks. Seven Liquid Level Sensors are mounted in each Sensor Tube.

4.5.1.2.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Solid State Optical Device with Controller	
Input Voltage:	24 VDC
Operating Temp:	-20° to 86°C (-4° to 186.8°F)
Current Consumption:	25 mA
Output:	TTL/CMOS compatible, may sink 40 mA up to 30 VDC
Controller Input:	12 VDC, 160 mA
Controller Output, (Switched):	500 mA max
Sensor Mounting Method:	NPT threaded housing
Weight [Kg (lbs)]:	.45 (1) (sensor w/leads) .91 (2) (controller)
Size [mm (in.)]:	44.4L X 17.5 dia (1.25L X .69 dia) (sensor) 101.6L X 127W X63.5H (4.00L X 5.00W X 2.50H) (controller)
Electrical Connection (Controller):	Screw Terminals

4.5.1.3 Water/Sediment Sensor (liquid interface) (S12)

The Water/Sediment sensor is a multi-level float switch installed in the sump of each fuel tank. The floats have a specific gravity that differentiates between fuel and water so that the sensor can indicate to the EEIM high and low levels of contaminants requiring action by operating personnel.

4.5.1.3.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Type:	Multi-level float switch
Float Specific gravity:	.90 min/1.05 max
No. of stations (floats):	2
Actuation Level:	50.8 mm (2.00 in.) (LOW) - 95.3 mm (3.75 in.) (HIGH)
Switch Type:	Low-normally closed

	High-normally closed
Mounting Method:	Flange Mount
Weight [Kg (lbs)]:	.91 (2)
Size [mm (in.):	50.8 dia X 254L max (2 dia X 10 Lg max)

4.5.1.4 Pressure Sensor, Liquid (S16)

The Liquid Pressure Sensor is used as an aid in monitoring the refueling process to verify proper operation of other components. It is also used to help diagnose other problems which may occur with the FSM. Pressure sensors are mounted at the base of each tank.

4.5.1.4.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Supply Current:	2.5mA w/no load at output at 24 VDC
Full Scale Output:	20 mA
0 Pressure Output:	4 mA
Loop Resistance:	750 OHMS
Operating Temp:	0° to 70°C (32° to 158°F)
Range:	0-1.73 MPa (0-250 PSIG)
Mounting Method:	NPT threaded housing
Weight [Kg (lbs)]:	.45 (1)
Size [mm (in.)]:	44.4 dia X 66.6L (1.75 dia X 2.62L)
Electrical Connection:	3 prong plug and socket

4.5.1.5 Temperature Sensor (S11)

The Temperature Sensor is located in the sump of each fuel storage tank to provide information to the EEIM regarding fuel/water temperature.

4.5.1.5.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Probe type thermocouple with stainless steel thermowell, polished aluminum protection head and Transmitter Module

Stem Length [mm(in.)]: 101.6 (4)

Thermocouple elements:	20 Ga. max
Temperature Range:	-10° to 150°C (14° to 302°F)
Transmitter Voltage:	24 VDC
Transmitter Output:	4-20 mA

Transmitter shall have isolated (input to output) thermocouple range

Thermowell shall mount to tank by means of NPT threads

Weight [Kg (lbs)]:	1.13 (2.5) (sensor assy) .23 (.5) (transmitter)
Size [mm (in.)]:	177.8L X 19.1 dia (7.00 lg X .75 dia) (thermowell) 88.9H X 88.6 dia (3.50H X 3.25 dia) (head) 88.6W X 31.8H X 101.6L (3.25W X 1.25H X 4.00L) (transmitter)
Electrical Connection:	Screw Terminals

4.5.1.6 Receptacle Sensor (switch) (S14)

The Receptacle Sensor is a switch located on the cover, or housing, of each fuel inlet. It provides an indication of which receptacle is being used so that the Vent Selector Valve may be positioned properly.

4.5.1.6.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Operation principle:	Roller Tip Plunger
Switch Type:	Reed type, hermetically sealed, normally closed contacts
Input Voltage:	9.6-55 VDC
Output:	3-200 mA
Actuator Travel Range:	2.03-16 mm (.08-.63 in.)
Method of Mounting:	Body Mounting
Weight [Kg (lbs)]:	.91 (2)
Size [mm (in.)]:	44.4W X 101.6H X 44.4L (1.75W X 4.00H X 1.75L)

4.5.1.7 Pressure Sensor, Vapor (S1)

The Vapor Pressure Sensor is used as an aid in

monitoring the refueling process to verify proper operation of other components. It is also used to help diagnose other problems that may occur with the FSM. The sensor is mounted in the vent manifold.

4.5.1.7.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Supply Current:	2.5mA w/no load at output at 24 VDC
Full Scale Output:	20 mA
0 Pressure Output:	4 mA
Loop Resistance:	750 OHM
Operating Temp:	0° to 70°C (32° to 158°F)
Range:	0-1.73 MPa (0-250 PSIG)
Mounting Method:	NPT threaded housing
Weight [Kg (lbs)]:	.45 (1)
Size [mm (in.)]:	44.4 dia X 66.6L (1.75 dia X 2.62L)
Electrical Connection:	3 prong plug and socket

4.5.1.8 Flow Sensor, Liquid (S15)

The Liquid Flow Sensor is mounted on the fuel outlet line between the pump and the FARV Auto Receiver. It provides verification to the EEIM that other components of the system have functioned properly to allow fuel flow.

4.5.1.8.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Paddle Wheel type with weld-on fitting/housing for 2 in. pipe

Operating Range:	1.5-30 FPS
Max Temperature:	149°C (300.2°F)
Operating Output:	Hz/GPM
Output Signal:	Sine wave
Output Frequency:	15 Hz per ft/sec
Output Amplitude:	0.4V/FPS
Source Impedance:	10K OHM
Weight [Kg (lbs)]:	2.72 (6)
Size [mm (in.)]:	101.6W X 101.6L X 152.4H (4W X 4L X 6H)

4.5.1.9 Valve Position Sensors

The Valve Position Sensors work in conjunction with the motor and solenoid operated valves to provide a means of indicating to the EEIM the current position of the valve. The sensor is an integral part of the valve actuator. The Valve Position Sensor consists of an auxiliary set of contacts on the valve actuator motor or solenoid which are cam-operated to prevent false indication of valve position.

4.5.1.10 Attitude Sensor

The Attitude Sensor provides information to the EEIM with regard to the side-to-side and front-to-rear attitude of the FARV. The EEIM uses this data to make adjustments to the fuel level sensor information being received. It is also used to provide data to the MMCS concerning whether docking can be accomplished.

4.5.1.10.1 Requirements/Characteristics

The following requirements/characteristics define the minimum acceptable design and construction parameters in generic terms applicable to the COTS component:

Input Voltage:	11 to 16 VDC
Power Required:	.3 W
Range:	±45° Both Axis
Output Function:	150 mV per degree
Operating Temperature:	0° to 80°C (32° to 176°F)
Output:	4 to 20 mA output
Weight [Kg (lbs)]:	1.36 (3)
Size [mm (in.)]:	127W X 50.8H X 101.6L (5.00W X 2.00H X 4.00L)

4.5.1.11 Relay Closure Sensor

The Relay Closure Sensor is an integral part of the Valve Actuating Relay. It shall provide the means of establishing an additional circuit used to verify the proper operation of the relay.

4.5.2 Controls

4.5.2.1 Pump Motor Control

The pump motor is controlled by the EEIM, which receives data from the processing computer. Those signals supplied to

the EEIM for pump control operate a contactor having contact ratings sufficient to carry the pump motor current. A sensor on the pump returns a feedback signal to the EEIM indicating the condition of the pump (running or stopped). The MMCS, via the EEIM, will send information to control the pumping duration.

4.5.2.2 Valve actuation (Electrical)

Valves are both motor and solenoid operated. Regardless of which type valve is in use, the computer, as programmed, will supply the necessary data to the EEIM which will operate relays or contactors associated with the valves. Proper feedback signals, indicating the status of the valves, will be sent to the EEIM and forwarded to the MMCS.

4.5.3 EMI/EMP

4.5.3.1 Grounding

For purposes of providing shielding of electronic equipment from the deleterious EMI and/or EMP effects, grounding and shielding of sensitive equipment and signal lines is necessary. Single ended signals, a voltage, usually ground the return line (ground) to the frame of the vehicle. The design of the FARV lends itself well to using the chassis as the ground return for signals. Signal shielding for double ended signals, a current, requires twisted pair shielded cable to exclude unwanted noise from disrupting normal equipment operation.

4.5.3.2 Filters/Filtered Connectors

Filters and filtered connectors plus shielding can greatly reduce the effects of EMI on the FARV electronics. They can prevent internally generated signals (noise) from escaping outside the FARV and interfering with other communication and electronic equipments as well as prevent external signals from disrupting FARV electronic operations. Not knowing what levels of EMI or EMP the FARV must withstand, only general concepts have been presented.

SECTION FIVE

DESIGN ALTERNATIVES (JUSTIFICATION)

5.1 INTRODUCTION

The purpose of this section is to present the justifications for the system architecture specified in Section Four and to discuss design alternatives explored while developing the afore mentioned requirements.

The design of the fuel system is predicated on the FARV New Start Chassis w/FARV Mission Module (FMM) concept and the space limitations inherent to the design presented by the ETOA.

This section is sub-divided into functional requirements which closely parallel the sub-modules of the system. These functional areas reflect mission requirements that are specified in the ORD and need not be repeated herein.

5.2 JUSTIFICATION

The following narrative provides the justifications/rational for the system and component recommendations contained in Section Four, System Architecture.

5.2.1 Fuel Receipt

The FARV Fuel System design requires the incorporation of three types of fuel receptacles. The three types are:

1. SARS
2. Manual Fill Port
3. FARV Auto-Receiver

Each type of receptacle fulfills a different field requirement and, together, enable the FARV to attain full mission potential.

5.2.1.1 SARS

The SARS fuel receptacle enables the Standard Army Refueling System Nozzle to refuel the FARV in not more than two minutes "on-the-move". The placement of a SARS receptacle on each side of the vehicle enables refueling without necessitating "maneuvering for position", thus expediting the refuel process. The redundancy in SARS Receptacles also ensures the "on-the-move" SARS refuel capability, even when one of the receptacles is subject to failure, battle damage, or is inaccessible for other reasons.

Incorporation of a detent switch, or sensor, at each SARS receptacle enables the system valving to vent displaced air and fuel vapor to the appropriate fuel fill point, thereby permitting the SARS Nozzle to scavenge the vent gases and eliminate a fuel vapor plume.

The recommended placement of the SARS receptacles is the result of analysis of available space and accessibility from the ground by dismounted personnel. The "Track Level Forward" placement of the receptacles also removes the refueling components from the immediate area of the MPU and the APS, both of which may be operating and emitting hot exhaust. Additionally, the crew of the FARV have immediate and full view of the SARS refuel operation and can resume assigned mission immediately upon completion of the refueling operation.

5.2.1.2 Manual Fill Port

The Manual Fill Port (receptacle) permits conventional fueling techniques and equipment to be used to up-load the FARV. The ports' aperture size will allow "Jerry Cans" and buckets to be used in the field, if need be, as well as typical filling station nozzles of various sizes.

Placement of the Manual Fill Port allows the tanks to be filled by gravimetric pressure. Under ordinary circumstances, the placement of the port on the top of the FARV also limits access by unauthorized personnel.

Incorporation of a sensor switch enables the valving to divert the displaced air from the tanks to vent from the Manual Fill Port.

The armored port cover is locked in place from the interior by a solenoid type device which can be manually overridden. The cover incorporates a labyrinth vent plug which permits the fuel system to aspirate during normal operation. The labyrinth vent, while allowing air to pass, will not allow flash or fire to enter the vent system and, thereby, ignite the fuel vapors found therein.

5.2.1.3 FARV Auto-Receiver

The FARV Auto-Receiver permits the FARV to be refueled by another FARV in the field.

The placement of the Auto-Receiver is dictated by the docking requirements of the FARV robotic transfer device.

Integration of bonding contact points and communication connections into the receptacle design enable the FARV receiving the fuel to control the transfer and to appropriately direct the vented gases to the Auto-Receiver vent pick-up.

The actual design of the Auto-Receiver is to be determined by the robotic arm with which it must interface.

5.2.1.4 SARS Manifold

The SARS Manifold connects the receptacle types to the fuel tanks (cells) and permits the apportionment of fuel via valving.

The tubular cross section of the manifold is derived from SARS "on-the-move" fuel flow requirements established by AMCR 70-17 and the Future Armored Resupply Vehicle Refuel Transfer Technology Final Report while the routing is defined by space allocation and prioritization.

5.2.2 System Venting

During refueling operations, The FARV Fuel System is a closed loop system. Gases that are displaced are returned to the point of origin, the receptacle. Since more than one receptacle is required to enable the FARV to be up-loaded by differing methods, selection, separation and/or diversion componentry is required to ensure the air/vapor is returned to the proper point. The following components satisfy vent flow parameters:

1. Vent Diverter Valve
2. Fuel/Air Separator
3. Vent Selector Valve

During normal operation the fuel system is considered an open loop system, with vent gases aspirating through a labyrinth plug to the atmosphere.

5.2.2.1 Vent Diverter Valve

The Vent Diverter Valve diverts the vent flow to the receptacle which is supplying fuel to the FARV, or to the manual fill port during normal operations. The SARS receptacle and the Auto-Receiver then scavenge the vent gases, thereby avoiding the creation of a vapor plume. The Manual Fill Port allows the gases to escape into the atmosphere during filling and transport operations. In the case of both the SARS and the Auto-Receiver, if the vent system is not connected to the receptacle being used to up-load the FARV, the speed at which the tanks are filled will cause back pressure to build up and reduce the flow. The diverter valve

is equipped with a sensor which monitors the valve position and sends the data to the EEIM upon request. The valves normal position vents gases to the Manual Fill Port for aspiration through the labyrinth plug.

5.2.2.2 Fuel/Air Separator

The Fuel/Air Separator is a fabricated item that uses centrifugal force to separate fuel droplets and "slugs" from the air displaced during refueling operations. The "on-the-move" SARS refueling operation will refuel the FARV at a fuel flow rate in excess of 662 LPM (175 GPM). This fuel flow rate may cause excessive turbulence which may be reflected by the presence of raw fuel in the displaced air flow. The Fuel/Air Separator will remove entrained fuel prior to the receptacle being used to up-load the vehicle, thus eliminating the probability of raw fuel spillage from the vent aperture.

5.2.2.3 Vent Selector Valve

The Vent Selector Valve permits the vent manifold to supply air displaced from another vehicle to the FARV fuel tanks during refueling of the AFAS or another FARV, thus preventing a partial vacuum from being formed in the on-board tanks. The valve is used in conjunction with the pump inlet and outlet valves. The selector valve is equipped with a sensor which monitors the valve position and sends the data to the EEIM upon request. The normal position for the valve permits vent gases to enter the Fuel/Air Separator.

5.2.3 Fuel Storage

The FARV New Start Chassis w/FMM concept dictates that the fuel system design incorporate three separate fuel tanks. One tank is positioned low in the chassis and effectively divides the propellant tanks from the Automated Ammunition Processing Station. The two remaining tanks are positioned on either side of the Projectile Storage Cell spaces, thus providing additional protection to those spaces.

Valving controls the fuel flow into and out of each tank while sensors monitor tank status and system activity.

5.2.3.1 Fuel Tanks (Cells)

The FARV is essentially an armored logistic supply transport vehicle whose mission is to maintain an AFAS at 100% stores and capability. The allocation of space on board the FARV is based on the prioritization of these logistic stores. The highest priority for space is given to the mechanisms, controls and volume required by the munitions.

The second level of priorities provides for the safety of the crew and the powertrain (engine and transmission). The third level apportions the remaining space to the Fuel System, C3,and Other Vehicular Equipment (OVE).

The fuel tanks will not be easily accessible nor repairable. Therefore, the material from which they are fabricated should serve "double duty", where possible. Some credible ability other than containment should be integrated into each fuel tank structure. The fuel tanks should have the capability of withstanding some, if not all, of the impact from small arms fire as well as percussion from "near miss" explosions. The fuel tanks will also be required to provide structural support for sensors and controls while providing for electrical bonding and ground. Steel tanks, properly treated against corrosion, are recommended.

The sump incorporated into the design of each fuel tank serves as a reservoir within which sediment and water collect. The depth of the sump is comparable to the sediment/water allocation required (5%) and allows a float type sensor to detect the depth of the contaminates. Each sump includes a port and control valve for draining the unwanted fluid and particulate matter overboard.

5.2.3.2 Valving, Tank Shut-Off

A Tank Shut-Off Valve is incorporated in the fuel supply, bottom loading, tube. This valve exercises precise control on the amount of fuel allowed to enter the tank during refueling or when transferring fuel from another on-board tank. The in-time actuation of the valve ensures that a 5% ullage is achieved. The valve is activated by the EEIM in response to a signal from the Hi-Level Sensor within the tank. The valve is monitored by an integral sensor which determines the valve position (open/closed) and sends the data to the EEIM upon request. The valves' normal position is closed.

5.2.3.3 Valving, Tank Transfer

A Tank Transfer Valve is incorporated into the scavenging tube of each fuel tank and which provides fuel to the transfer pump for off-loading. The valve also permits fuel to be transferred to another on-board fuel tank. The valve is activated by the EEIM in response to a signal from the MMCS. The valve is monitored by an integral sensor which determines the valve position and sends the data to the EEIM upon request. The valve is normally closed.

5.2.3.4 Tank Drain Valves

The Tank Drain Valve in the base of each fuel tank sump provides the means by which the fuel tank can be drained of contaminants (water/sediment). The valve is actuated by the EEIM in response to a command issued by a crewman via the MMCS. The valve is closed unless activated.

5.2.3.5 Sensors, Tank

Sensor are incorporated into the design of each fuel tank to aid in determination of fuel status. Most of the sensors are located within the "Sensor Tube", positioned at the geometric center of the fuel tank, for ease of maintenance and/or repair.

5.2.3.5.1 Hi-Level Sensor

A Hi-Level Sensor is placed in each fuel tank (cell). The sensor is required to ensure that 5% ullage is maintained in the fuel tank during refueling operations. The sensor is a solid state device which will generate a signal upon immersion in fluid (fuel). The signal generated will initiate stop valve closure via the EEIM. A solid state optical device is recommended for durability and cost considerations.

5.2.3.5.2 Lo-Level Sensor

A Lo-Level Sensor is placed in each fuel tank (cell). The sensor is required to establish the level of fluid in the tanks. The signal generated by the sensor may also be used by the EEIM to initiate valve closure to prevent air from being scavenged by the FTM or VFM. A solid state optical device is recommended for durability and cost considerations.

5.2.3.5.3 Fuel Level Sensor

Seven (7) Fuel Level Sensors are placed in each fuel tank at predetermined heights to monitor the amount of fuel in the tank. The sensors are required to ascertain the amount of fuel that is in each tank. Signals from the sensors are combined by the EEIM, compared with attitude readings, and the sum is forwarded to the MMCS at regular intervals. A solid state optical device is recommended for durability and cost considerations.

5.2.3.5.4 Water (Float) Sensor

The Float Sensor is positioned in the sump of each fuel tank. The float has negative buoyancy in fuel and positive buoyancy in water. Thus, the sensor differentiates between the level of contaminants (water/sediment) and fuel. The sensor device is designed to initiate high and low level signals. The high level signal corresponds to the maximum sediment allowance (5%), while the low level corresponds to approximately 0.5% sediment allowance. The high level signal initiates a que to the MMCS. This que initiates a visual query/statement/recommendation by the MMCS as to action to be taken by the crew. The crew determines if the current situation/environment is applicable to the recommended action of water/sediment drainage. When applicable, the drain valve for the tank is actuated and remains open until the low level position is approached. When the low level point is reached, the discontinuance of the sensor signal initiates valve closure via the EEIM.

5.2.3.5.5 Temperature Sensor

The Temperature Sensor is positioned in close proximity to the sump of each fuel tank. The calibrated sensor enables the EEIM to determine the temperature of the fluid in each tank and initiate action as required by the firmware. The sensor is located in close proximity to the sump because any water in the tank will be limited to the confines of the sump. If temperatures approach that at which water freezes, the plug type tank heaters will be activated by the EEIM, thus ensuring against possible damage to the tank and lower valving due to freezing. If the temperature exceeds a predetermined point, it is compared to other tank temperatures. The tank which is coolest is the tank to which warm fuel is recirculated to by the VFM three position return valve.

5.2.3.5.6 Pressure Sensor

A Pressure Sensor is installed in the top of each tank to determine if a hazardous condition exists due to vent blockage or fire-on-board. A rapid change in pressure during refueling operations is indicative of a vent blockage while similar change during transport, or combat conditions, may reflect the effect of exposure to heat (fire on board).

5.2.3.6 Attitude Sensor

An Attitude Sensor is installed in the base of the FARV hull. The sensor is aligned with/to the longitudinal and latitudinal axis of the vehicle. Changes in vehicular atitude are continually forwarded to the EEIM and the MMCS. The Attitude Sensor provides data that dictates the capabilities and capacity for docking in any terrain.

5.2.4 Fuel Use

The use of fuel by the FARV is limited to consumption by the MPU and APS. The APS is assumed to be powered by a fuel consuming internal combustion engine. At full load, the MPU is expected to consume 294 liters/hr (77.7 Gal/hr) of fuel, or 4.9 LPM (1.29 GPM). The APS fuel demand is reported to be not more than 164 liters (43.3 gallons) in a 12 hour period, or 0.17 LPM (0.4 GPM).

Fuel will be stored for on-board consumption in the same fuel tanks that carry fuel destined to be up-loaded to the AFAS or another FARV. Bottom loading scavenger tubes will supply fuel from the Down Tank and both Saddle Tanks, via a 3-position selector valve, to the VFM fuel pump. Tubing and reinforced hose, 3/4 in., is used to reduce flow restriction and to avoid the formation of ice in the suction tube as well as lessening the probability of sediment pick-up. A 3-Way Valve directs the fuel flow to the operating unit(s). The fuel that is not consumed is returned to the tanks via another 3-Way Valve and Tank Selector Valve.

5.2.4.1 Tank Selector Valve, Supply

The electrically operated Supply Tank Selector Valve permits the EEIM to obtain fuel from any one of the three on-board tanks or to shut off the fuel supply to the MPU and APS. Operation of the valve is both automatic and "on demand". Upon start-up, the choice of tanks, from which the fuel is to be supplied, may be controlled by a crewmember or left to the firmware residing in the EEIM. When left to the EEIM, the choice of tanks is dependant upon the level and temperature readings from sensors in each tank. During operation, the choice of tanks is made by the EEIM, based on similar parameters. The presence and correct operation of the Supply Tank Selector Valve ensures that the MPU and APS are continually supplied fuel, and that the fuel tank temperature remains below the fuel flash point except when operating in climatic condition, hot.

5.2.4.2 Fuel Pump

The size and capacity of the fuel pump is 50% over the reported maximum fuel consumption of the FARV. This capacity accounts for a safety factor of 20% and any losses due to valving and routing.

The placement of the pump and motor assembly in the engine compartment permits access for repair/replacement. The operational parameters for the unit are those identified with the engine compartment environment.

A DC electric motor is used to drive the pump. It has sealed ball bearings and an explosion proof housing to ensure long life. The pump is face mounted to the motor to economize the use of space and to allow replacement of the pump and motor as a single assembly. Vibration isolation mounts and brackets are recommended to isolate the pump and motor assembly from drive train vibration while also reducing the vibrations transmitted to the tubing, hose, and fluidic connections.

5.2.4.3 Fuel Filter/Separator

Water and solid particulate matter is removed from the fuel flow by the Fuel Filter/Separator. Emulsified water to 0.5% is separated from the fuel and deposited in the base of the unit for later removal. Particulate matter greater than 25 microns is removed by the replaceable filter cartridge. Battlefield conditions cannot guarantee the condition of fuel on receipt, nor can an open vent system prevent the accumulation of condensate (water) from building up over time in storage or extended periods of inactivity. Fuel, free of contaminates which could immobilize the vehicle, is absolutely necessary to fulfilling the FARV mission. Therefore, the Fuel Filter/Separator is required.

The placement of the Fuel Filter/Separator in the engine compartment permits access for maintenance and repair/ replacement. The operational parameters for the unit reflect placement within the environment of the engine compartment.

Vibration isolation mounts and bracketry are recommended to isolate the Filter/Separator from drive train vibration while also reducing exposure of the tubing, hose, and fittings to vibration.

5.2.4.4 3-Way Fuel Valve, Supply

The electrically operated 3-Way Fuel Supply Valve enables the fuel to be directed to the MPU alone, the APS alone, or to both at the same time. The operating parameters for the valve reflect its placement within the confines of the engine compartment.

5.2.4.5 3-Way Fuel Valve, Return

The electrically operated 3-Way Fuel Return Valve works in parallel with the 3-Way Fuel Supply Valve by directing fuel away from the operating system(s). The operating parameters for the valve reflect its placement within the confines of the engine compartment.

5.2.4.6 Tank Selector Valve, Return

The electrically operated Return Tank Selector Valve permits fuel unused by the MPU and APS to be returned to the same or different tank from which it came. This allows the EEIM to ensure that fuel temperatures in the tank(s) are controlled and remain below the fuel flash point.

5.2.4.7 Transshipment of Fuel

While the primary function of the above components is to provide fuel to the MPU and the APS, they may also be used to transfer fuel from one fuel tank to another at a flow rate of 7.57 LPM (2 GPM). This secondary capability permits fuel to be transferred out of one fuel tank and into another by means other than the primary FTM components.

5.2.5 Fuel Transfer

The transfer of fuel from the on-board fuel storage tanks to an AFAS or another FARV is part of the primary mission of the FARV. The rate of fuel transfer is required to be 132-190 LPM (35-50 GPM).

Valved, bottom loading, scavenger tubes, 2 inches in diameter, supply the transfer pump which off-loads the fuel to either the robotic docking mechanism or the Hose Reel and Nozzle Assembly. Valving which enables the secondary functions of defueling and transshipment is located on either side of the pump assembly. A Fuel Filter/Separator insures that the fuel is free of contaminants and emulsified water.

5.2.5.1 Fuel Transfer Pump

The Fuel Transfer Pump provides fuel at 189.25 LPM (50 GPM) at 30.48 meters (100 ft) head. This capacity is

provided to ensure that the AFAS is fueled in accordance with the specification requirements even though the restrictions and flow impedance of the robotic appendage are not known.

The placement of the pump and motor assembly in the lower chassis is the result of space prioritization. Access to the assembly is limited and maintenance and replacement may require off-loading of the logistic munitions load.

A DC electric motor is used to drive the pump. The motor and pump are equipped with sealed and lubricated bearings and explosion proof housings to ensure long life. The pump is face mounted to the motor to economize space usage and to permit replacement as a single unit.

Vibration isolation mounts and bracketry are recommended to isolate the assembly from drive train vibration while also reducing the vibration transmitted to the tubing, hose, and fluidic connections.

5.2.5.2 Valve, Pump Inlet

The directional control valve placed at the inlet to the fuel transfer pump enables the FARV to defuel a disabled AFAS or another FARV through either of its SARS receptacle ports, as well as off-loading fuel from the on-board tanks. While enabling defueling, it does not allow SARS defueling rates of one-half the normal refuel rating for either vehicle. This capability permits the recovery of fuel in an environment where fuel supplies are often critical. Sensors monitor the valve position and communicate the data to the EEIM upon request.

In its normal position, the valve enables the pump to scavenge fuel from the on-board fuel tanks for refueling the AFAS or another FARV.

5.2.5.3 Valve, Pump Outlet

The directional control valve placed at the outlet of the transfer pump, along with the Fuel Transshipment Valve, enables the FARV to transfer fuel from one fuel tank to another at 132-190 LPM (35-50 GPM), as well as transfer fuel to an AFAS, another FARV or overboard for maintenance. This capability allows a damaged fuel tank to be emptied with minimal loss of fuel and also limits the amount of fuel that might otherwise be trapped in the bottom of the hull. The valve is equipped with a sensor which monitors its position and transmits the data to the EEIM upon request.

In its normal position, the valve enables the pump to off-load fuel through either the robotic refueling mechanism or the Hose Reel and Nozzle Assembly.

5.2.5.4 Valve, Fuel Transshipment

The Fuel Transshipment Valve, along with the Pump Outlet Valve, permits fuel to be transferred from one on-board fuel tank to another. This allows use of fuel made inaccessible for on board use by selector valve failure. The valve also allows fuel to be rapidly removed from a leaking, or holed, fuel tank and transferred to a functional fuel tank (cell). As much as 567.8 liters (150 gallons) of fuel might be lost, or be made unaccessible, without this valve. The valves' normal position permits refueling.

The Fuel Transshipment Valve is equipped with a sensor which monitors the valve position and sends data to the EEIM upon request.

5.2.5.5 Fuel Filter/Separator

The Fuel Filter/Separator eliminates particulate matter and water from the fuel flow prior to its being transferred to an AFAS or another FARV. Battle field refueling conditions cannot guarantee the condition of the fuel upon refueling, especially when the operation is conducted in inclement weather. Moist air within the on-board fuel tanks can precipitate water when cooled. Vibrations from the drive train and cross country travel can cause both water and sediment trapped in the sump of each fuel tank to be suspended in the fuel and sucked in the Transfer Pump supply tube.

The placement of the Filter/Separator in the lower chassis is predicated upon space prioritization. The filter elements may be accessed for replacement by removal of panels or doors, adjacent to the fuzing mechanisms.

The Filter/Separator is equipped with a sensing device which can ascertain filter status and a valve which can dump overboard the water accumulated in the base of the housing, automatically or when instructed by the EEIM.

Vibration isolation mounts and bracketry are recommended to isolate the Filter/Separator from drive train vibration while also reducing exposure of the tubing, hose, and fittings to vibration.

In order to fulfil its mission requirements, the FARV must supply uncontaminated fuel to an AFAS or another FARV. It is therefore mandatory that a fuel filtration device be incorporated into the FTM design.

5.2.5.6 Valve, Manual Off-Loading

The Manual Off-Loading Fuel Valve permits fuel to be off-loaded to other combat and support vehicles not equipped with Auto-Receivers. Used in conjunction with the Hose Reel and Nozzle Assembly, the FARV can transfer fuel at rates up to 189 LPM (50 GPM). This manual valve is operated from the vehicle exterior by dismounted members of the crew after the armored valve access panel is unlocked from the interior of the vehicle.

5.2.5.7 Hose Reel and Nozzle Assembly

The Hose Reel and Nozzle Assembly is used to transfer fuel to other vehicles in unusual circumstances. The assembly does not normally contain fuel and is mounted on the exterior of the vehicle. The capacity for such fuel transfer may be optional since the same capacity is attained by using the SARS Receptacle and setting the Fuel Pump Outlet Valve and Transshipment Valve for off-loading.

5.2.5.8 Rotary Union

The rotary union and flexible vent tube are the logical choice for interfacing with the robotic arm that will accomplish FARV/AFAS fuel transfer. Other mechanisms may be used to facilitate transfer of fuel to, and through the robotic arm, depending upon the final design configuration of the automated fuel and munitions transfer system.

5.2.6 Refueling Without Power

The FARV Fuel System is designed to enable "On-the-move" SARS refueling. The design also permits defueling via SARS nozzle and system components. Depending upon FARV vehicular status, various options are available to enable refueling/defueling of a "powered-down" FARV. These options are dependant on valve settings in the event of power loss or valve positioning using external power. Valves may also be changed manually if "powered-down" and designed for such operation.

5.2.6.1 External Power

When refueled/defueled via the SARS receptacles, the EEIM can obtain operational power from the service facility or vehicle. By utilizing external power the vent control and fuel control valving can be positioned for the appropriate

receptacle. External power can also be used to transfer fuel via the AFAS/FARV robotic transfer arm.

5.2.6.2 Unpowered, Limited, Operation

The valving incorporated into the design of the FARV Fuel System is normally closed when in transport, or when moving from one position to the next. However, upon loss of power, springs may change the position of the vent and fuel valving to allow unpowered refuel/defuel operations to be conducted using one of the SARS receptacles and external SARS equipment.

An alternative option allows the vent and fuel control valves (V1 and V11) to be manually operated from the crew space. Only the fuel tank valves (V2) need be open when unpowered.

5.3 ALTERNATIVES

The following narrative defines the alternatives explored while determining the recommendations in Section Four, System Architecture.

5.3.1 System Architecture, Singular vs. Dedicated Usage

The FARV Fuel System design is predicated on space limitations and specific mission parameters. While the fuel system has been defined by these parameters, it is likely that an optimized fuel system would reflect a similar design. The only exception might be in the allocation of fuel tanks as singularly reserved for logistic resupply and on-board use versus multiple usage.

The FARV up-loads logistic supplies to the AFAS upon demand or after each fire mission in order to maintain the AFAS at 100% mission capable. The fuel used to resupply the AFAS is also used to power the FARV. Should the distance to the LRP become greater than presupposed, the FARV is in danger of running out of fuel and, thusly, becoming incapable of carrying out its mission. The recommended system architecture includes the sizing of one of the fuel tanks, and its scavenging tubes, so that the off-loading capabilities of the FARV do not exhaust the on-board fuel supply. Rather, approximately 75 liters (20 gallons) of fuel is reserved for on-board use.

The multiple fuel tank (cell) design limits the amount of fuel that might be subject to loss from leakage or battle damage. Multiple fuel tanks also increase the amount of controls and sensor devices required to monitor fuel system operation. Redundancy in tanks increases the probability of the FARV remaining mission capable, even if partially limited by damage.

Were space available, or prioritization altered to benefit

fuel storage, the separation of fuel for on-board use and for resupply might be advantageous. Closer monitoring of fuel stores could be accomplished and further compartmentalization could increase safety for the crew.

5.3.2 Manifold Design

The design of the fuel supply and return manifolds is predicated on fuel flow requirements and secondary capabilities. The size of the aperture and tubing cross section is derived from SARS refuel/defuel requirements while the routing of the manifold tubing is subject to space limitation/allocation.

The manifold design recommended increases the capabilities of the FARV disproportionately to the additional space requirements. The combination of valving, sensors, and manifolding permits:

- SARS refueling at "on-the-move" rates near 750 LPM (200 GPM)
- SARS defueling at 375 LPM (100 GPM)
- filling of tanks in series or parallel
- transshipment of fuel between fuel tanks
- fuel recovery from an immobilized vehicle (SARS equipped)
- rapid up-load of fuel to an AFAS or another FARV

The alternative use of a single manifold and reduced valving will negate the ability to transship fuel from one fuel tank to another and the ability to defuel a SARS equipped vehicle that has been immobilized by battle damage or power loss.

The incorporation, into the design, of dedicated fuel supply and vent return manifolds ensures that SARS refueling rates can be met without requiring single fuel tank implementation and limiting the length (distance) the fuel must travel before reaching the tank(s). The "same size" vent manifold reduces the buildup of pneumatic pressure and subsequent hydraulic pressure pulsation in the fuel supply manifold. The reduction of pneumatic pressure enables the use of light weight, thin wall, tubing in the design and manufacture of the vent return manifold.

The dedication of the fuel supply manifold to FARV refueling and SARS defueling enables the manifold to be supplied fuel via various types of fuel ports. The separate fuel transfer tubing and hose system permits refueling and defueling at lower than SARS rates, and from restricted fuel ports. "On-the-Move" definition requires that the fuel fill ports used for SARS be sized in accordance with specific fill rates and be easily accessible. The

accessibility of the fill ports may not permit FARV/AFAS refuel operations to be optimized. The position of the automated ports also negate unassisted drain-down of fuel without external equipment (SARS).

Down-sizing, of either, the vent manifold tubing or the fuel manifold tubing will result in an increase in fuel and vent pressure. Increased pressure will generate flow problems and may create hydraulic and pneumatic reverse pressure waves. Higher strength tubing and materials will be required to contain the increased pressures.

5.3.3 Power

Power is consumed by the recommended fuel system components in the form of electrical energy or resistance. The energy is primarily consumed by the generation of mechanical motion in valving, the change in resistance of sensor devices, and by the generation of reciprocating or rotational motion in pumps.

5.3.3.1 Electrical

COTS and NDI are available that meet most of the requirements of the FARV Fuel System. The majority are electrically operated, or driven, and require little or no modification for FARV Fuel System service.

The availability of replacement units and spare parts is high, enabling emergency field repair without resupply from single source manufacturers.

Electrical power is a prerequisite of C3 and is easily transmitted by cables and wires through tight places and inaccessible areas. It is therefore the power source of choice.

5.3.3.2 Hydraulic

Hydraulic powered valving, controls, and motors (rotors) are available to a limited extent, worldwide. The size is generally that applicable to large chemical or raw material processing facilities and, therefore, too large for FARV use, or applicable to the aerospace industry where high pressures predominate.

Hydraulic power components are often subject to high fatality rates and maintenance requirements when exposed to extremes in temperature and "dirty" environments. The routing of fluid hoses would further burden space allocation within the chassis.

Sensor devices are not available and control devices would require yet another interface to communicate with the EEIM or MMCS. Thereby creating a fuel system with two power requirements.

Two sources of hydraulic power would be required. The primary hydraulic power source would be driven by the MPU and the secondary hydraulic power source would be required to be driven by the APS.

5.3.3.3 Pneumatic

Pneumatic powered valving, controls, and motors are available. Pneumatic powered sensors do not exist. The amount of energy expended to power pneumatic devices is more than that required for similar electrical or hydraulic devices.

Air driven devices exhaust air upon use. Therefore, the system losses would be high and the probable noise level within the hull of the vehicle could be deafening. An air pump and reservoir are required to provide the power reserves necessary to drive large valves. The space needed for the equipment necessary to provide the volume of air required by a 189 LPM (50 GPM) pump could be prohibitive for incorporation into the close confines of the FARV.

Electrical power is required for signal generation and activation of controls.

A pneumatically powered fuel system would require, like the hydraulically driven system, twin power sources.

5.3.3.4 Mechanical

Mechanical force, rotational or reciprocating, can only be used, directly, to drive the two fuel pumps. System valving, controls, and sensors would require another power source. Mechanical drives would necessitate the incorporation of additional mechanical components such as bearings, rotary and universal couplings, clutches, speed reducers and increasers, and other power transmission components.

5.3.4 Inlet (receipt) Valving

When multiple fuel tanks are dictated by space prioritization and/or design, valving ensures that the ullage requirements are met. If a singular fuel tank was to be filled, sensors could signal that the proper level of fuel was reached and stop the refueling operation.

An alternative to valving of the inlet lines would be to incorporate ball check valves into the vent apertures. Ideally, when the proper fluid level was reached, the ball valve would shut off the vent passage and produce back pressure which would force the fuel into another tank or back up the fill tube to the receptacle. However, the turbulence caused by rapid filling operations (SARS) and the probability that some refueling operations will be conducted on sloped terrain invalidate the accuracy of ullage maintenance.

5.3.5 Component Redundancy

Component redundancy is desired in all FARV systems to insure that failure of a single LRU does not prevent the primary mission from being achieved. Although desirable, component redundancy creates additional control requirements, space and weight demands. The recommended FARV Fuel System demonstrates redundancy for the following equipment items:

- Fuel Storage Tanks (Cells)
- Receptacles
- Valving
- Sensors

5.3.5.1 Transfer Pump Redundancy

A Redundant transfer pump would impact both space and weight constraints. The capability exists to off-load fuel using gravimetric force by using the VFM Pump to pump fuel to the saddle tanks. The fuel would then flow through the centrifugal transfer pump at a much slower rate. The FARV may also be defueled in accordance with SARS requirements.

5.3.5.2 Vehicle Fuel Pump Redundancy

Space limitations prevent the incorporation of a separate and redundant circulation pump. Depending upon the type of MPU (turbine vs. diesel) that is incorporated into the FARV, a pump may prove unnecessary. Gravimetric pressure and/or the engines' own pump may have adequate suction to provide fuel for its' use.

Redundancy in function is accomplished by the incorporation of a fuel line from the roadside Saddle Tank to the primary fuel line. This permits fuel to flow to the MPU and APS using gravimetric pressure.

5.3.5.3 Filter/Separator Redundancy

While deemed necessary, fuel filtration is bypassed when an overpressure condition is sensed, as in filter clogging or water saturation. Separate Filter/Separator units are also

space prohibitive.

5.3.6 Fuel Contamination

Fuel obtained at the LRP is "acceptable for use" and is deemed not to require conditioning or filtration. Therefore, the incorporation of a filtration and water separation device capable of operating at 757 LPM (200 GPM) is deemed unnecessary.

Evaluation and analysis also indicated that such a Filter/Separator would be approximately 762 mm (30 in.) in diameter, 1,524 mm (60 in.) high, and weigh in excess of 544.3 Kg (1,200 Lbs). Such an item of equipment is not acceptable for FARV consideration.

5.3.7 Pump (Types)

The FARV Fuel System has two sub-systems which require fluid pumps, the VFM and the FTM. While the volummetric and pressure requirements of each module vary, they share other prerequisites. Both pumps are required to be small and light weight, simple in construction with proven reliability, quiet and vibration free. Additional parameters taken into consideration include: the ability to be end, or flange, mounted to the DC motor; be self-priming; resistant to the corrosive effects of water and chemicals used to decontaminate military equipment; not subject to degradation when exposed to petrochemical fuels and their additives; and capable of operation from -46° to +49°C (-50.8° to +120.2°F).

Various pumps were evaluated which are encompassed by either centrifugal or positive displacement design. Basically, centrifugal pumps were found to be more dependable, smaller, lighter and available in a wider range of options than positive displacement pumps.

Positive displacement pumps include diaphragm pumps, piston pumps, vane pumps, gear pumps, and screw pumps, among others. These pumps are characterized by close running tolerances and multiple components which contribute detrimentally to MTBF. Positive displacement pumps also have minimal flow rates when compared to similarly sized centrifugal pumps.

5.3.8 Fuel Control

The automation of the logistic resupply mission requires that controls, sensors, and mechanisms be introduced into the design of a vehicular platform. To date, designs incorporating similar types of equipment have been stationary installations not subject to the rigors of a battlefield (combat) environment.

The fuel system may require as many as sixty separate control signals to be monitored on a continual basis. Many of these signals (data) will be required to be compared to resident data (firmware). The comparison will result in a singular item of concern to the operational parameters of the FARV (i.e., fuel level of system). This simple data/signal monitoring function should not be required to be resident to the MMCS. Rather, it should be included within the fuel system requirements.

Additionally, the operational demands of the fuel system require that electrical control devices, like relays and contactors, be used to energize the sub-system valving and pumps. As many as eighteen relays and/or contactors of various sizes may be required to adequately control the system functions. The space required for these control components is not insignificant, and should not further burden the MMCS.

The EEIM can be subdivided into two, or more, groups of equipment which can be placed in areas isolated from the main electronics spaces. Emissions from the closure of contacts and similar devices can be reduced by distance, as well as grounding, from the MMCS.

5.3.9 Stress

The stresses encountered by the FARV Fuel System componentry are resultant from its' environment, mode of transport and the type of chassis within which it resides. The design of the system, and the materials from which it is fabricated, shall be adequate to the challenges of shock, vibration, severe cold and extreme heat.

5.3.9.1 Environmental Stress and Exposure

The FARV Fuel System must operate at temperatures from -46° to +49° centigrade (-50.8° to +120.2° fahrenheit). Storage and transport temperatures increase the possible limits of exposure up to 20%. The components used in the system must survive exposure and function without failure or degradation. Coefficients of expansion and contraction must be allowed for in the design of fuel lines, fittings, valves and fuel tanks. Service loops and flexible tubing shall be taken. Thermal insulation shall be used to limit condensation and subsequent corrosion and possible accumulation of moisture on electrical componentry. Seals and gasket material shall be chosen for elasticity and stability at the temperature extremes. The use of ultralight materials, such as plastics, shall be predicated upon their physical characteristics at the temperature extremes.

5.3.9.2 Shock and Vibration

The severity of shock and vibration is attributable to the battle environment and chassis design of the FARV. The fuel system shall withstand cross-country and obstacle generated chassis shocks of up to 3 Gs. The track-type propulsion will generate synchronous vibration. The fuel tanks and fuel lines shall be isolated by vibration absorbing shock mounts suitable to ensure survival and operational integrity. Valves and control components shall incorporate "transport/mobility" modes which lock moving parts in a specific position, thus ensuring against damage. The proposed fuel system routing attempts to follow bulkheads and chassis definition as is appropriate to minimize unsupported lengths of tubing/hose while utilizing space not occupied by systems critical to the FARV mission.

SECTION SIX

SYSTEM RELATIONSHIPS

6.1 INTRODUCTION

The purpose of this section is to identify the inter-relationships of the FARV Fuel System with other on-board systems. The relationships are driven by fuel system design and the FARV operational mission. The importance of the relationship is rated with reference to the FARV mission.

6.2 INTERFACE REQUIREMENTS

The interface requirements of the FARV Fuel System and its modules are mechanical, electronic (as in communication), electrical, or a combination of aspects.

6.2.1 Primary

The primary interface requirements are those directly related to the storage, transport and transfer of munitions, propellant and fuel.

6.2.1.1 Robotic Transfer

The FARV supplies munitions, LP and fuel to the AFAS, or another FARV, via an automatic system which permits the crew to initiate and manage the transfer of logistic supplies without leaving the confines of the armored compartment. This automatic system uses a robotic appendage to dock with another vehicle, equipped for the purpose, and physically transfers the aforementioned material.

The Fuel System components, major and minor, are located in areas of the chassis that are not dedicated to the storage and/or handling of munitions and LP. Such is the status of the design effort for the robotics that determination of what mechanisms will be required to interface with it is only hypothetical. Never-the-less, the fuel system must interface mechanically with the robotic appendage in order to transfer fuel.

Additionally, it is likely that the Down (belly) Tank of the FARV will form a partition between the LP tanks, robotic appendage and the aft sections of the chassis, effectively compartmentalizing the lower part of the hull. The Saddle (side) Tanks are positioned on either side of the projectile storage cells, partially sheltering the load from the effects

of small arms fire. Tubing and/or pipe and hose will be routed through munitions spaces to permit fuel to flow at predetermined rates during refueling and transfer.

6.2.1.2 MPU/APS

While the mission requires the storage and transfer of munitions and fuel, the vehicle must be capable of reaching the point of transfer and/or resupply. The fuel system supplies fuel to both the MPU and the APS. The majority of the VFM components are located in, and accessible through, the engine compartment. Actual interfacing is accomplished by tubing and fittings which provide the engine(s) access to the circulating fuel.

6.2.1.3 C3

The Fuel System includes in its design a number of valves and sensors which control fuel flow and provide the means by which the system may be monitored. The FARV personnel perform docking and logistic transfer of material with the aid of the MMCS. This computerized and automated system interfaces with the operational sub-systems on board the FARV, including the fuel system. The MMCS maintains data regarding logistic resources as well as maintenance and repair requirements while aiding the crew in the conduct of C3 tasks.

The EEIM provides the control and monitoring interface required to operate the fuel system without burdening the MMCS with spurious input that requires comparison and summation prior to its use. The EEIM interfaces with the MMCS and the electrical/electronic components of the VFM, FSM and FTM via wire and cabling.

6.2.2 Secondary

The secondary interface requirements are those not directly related to the storage, transport and transfer of logistic material to an AFAS. The secondary interfaces include: the display of status information to the crew; Manual Fill Port, SARS Receptacles and Auto-Receiver; and the manual fuel off-loading capability.

6.2.2.1 Data Display

Fuel system status and sensor data is continually supplied to the MMCS by the EEIM. The crew can access this data, or a derivative thereof, by querying the MMCS. The requested data will be displayed on the MMCS display. However, certain items of information that pertain to the Fuel System may be signaled to the crew independent of the

MMCS. These items will reflect maintenance factors which may result in system degradation. The crew will be both visually and audibly informed of the pending situation. Visually by either a specially designed control panel or by a LCD panel, and by the emittance of an audible warning tone.

6.2.2.2 Fuel Receipt

The interface requirements of the fuel receptacles vary by application; manual vs. semi-automatic (SARS) vs. fully automatic (Auto-Receiver). All three types of fuel receptacles interface mechanically with the armored exterior of the vehicle. In addition, the semi-automatic receptacles must be compatible with a SARS nozzle, and the automatic receptacle must interface with another FARVs robotic appendage (arm). The automatic receptacle must also provide an electronic/electrical interface that enables both power and control to be transferred to the receiving vehicle.

6.2.2.3 Fuel Off-Loading, Manual

The capability to refuel other vehicles in the field is secondary to the primary mission of the FARV. It requires that the manual refueling components be compatible with the various fill port types found on combat and support vehicles. The Hose Reel and Nozzle Assembly must be capable of being handled and used to dispense fuel by one crew member. The Hose Reel and Nozzle Assembly interface with the exterior armor of the FARV and must not interfere with vision or docking maneuvering.

6.3 IMPACT

The FARV Fuel System occupies, approximately, 2.83 cubic meters (100 cubic feet) of interior space and weighs approximately 2,169.4 Kg (4,782.7 Lbs.), (see Appendix D), of which 1.5 cubic meters (52.8 cubic feet) and 1,173.4 Kg (2,587.3 Lbs.) is fuel. The Fuel System supplies fuel to the MPU and APS. The EEIM interfaces with the MMCS for operational and maintenance direction. Loss of most singular fuel system components results in "graceful degradation" of the systems' capabilities.

SECTION SEVEN

SAFETY AND HUMAN FACTORS ENGINEERING

7.1 INTRODUCTION

This section identifies the minimum Safety and HFE credentials which must be adhered to for adequate operation and maintenance of the FARV. No attempt to minimize the importance of crew safety or HFE is made in light of the combat mission of the FARV. An evaluation was conducted (see Appendix C) to determine effects of component failure and safety hazards.

7.2 SAFETY

The operation, test, and maintenance of the FARV Fuel System shall not present a hazard to the crew during employment in peacetime or battlefield (combat) conditions.

The following guidelines are those deemed necessary to establish a safe environment for the FARV crew. They are not listed in any relation to importance or priority, each is a "stand-alone" requirement.

- Fault logic resident to the EEIM shall detect errors in order to minimize incorrect crew entries which may cause,or contribute to, hazardous conditions. Errors shall be made obvious to the operating system and the crew by the generation and communication of a fault code to the MMCS.

- Software/Firmware resident to the control system shall enable manual override of automatic functions, in emergency situations, that do not create additional hazards to the crew or vehicle.

- The electrical/electronic components of the fuel system shall be shielded against emanation of Radio Frequency (RF) considered deleterious to the crew or vehicle.

- Componentry from which the fuel system is assembled shall not initiate, nor support, combustion.

- During normal operation, the electrically actuated, or responsive, components of the fuel system shall be inaccessible to the crew.

- All components of the fuel system shall be at the same potential as the chassis. All bonding shall be permanent.

- Access to the fuel system components shall be via covers, panels, and doors appropriately marked and equipped with safety switches.

- Connectors and plug/receptacle pairs shall be of such design as to eliminate the possibility of mis-connection. Connector pins shall not be normally energized after disconnection from socket contacts.

- Fuel pumps, valves and sensors shall have no exposed moving parts.

- Fuel System access panels, covers, doors and operating controls and displays shall be adequately marked with regard to function and/or caution/danger exposed.

- Fuel pump circuitry shall be protected by an appropriately sized circuit breaker accessible from the crew compartment.

- Valving circuitry shall be protected by circuit breakers accessible from the crew compartment.

- Overload and overvoltage protection shall be provided for all circuits transmitting power to fuel system components.

- Methods of fabrication and assembly shall be such as to prevent raw, sharp and rough edges on the finished and installed equipment items/components.

- Non-skid surfaces and hand holds shall be provided to ensure safe access to the Manual Fill Port.

- No fuel system component or module failure will result in the discharge of ordnance or vehicular motion.

- The FARV Fuel System will not significantly contribute to the noise levels at the operational crew stations.

- During normal operation, the fuel system shall aspirate through a "labyrinth" or "breather" vent plug which shall not permit flash, or flame, to propagate from the exterior of the vehicle into the fuel system.

- Pressure release valves shall be incorporated into the design of each fuel tank, reducing the probability of rupture or bursting due to fire.

- Ullage shall be maintained in each fuel tank at not less than 5% of the total tank volume to ensure against hydraulic ram effects caused by ballistic penetration.

7.3 HFE

The FARV Fuel System is part of the automated Rearm/Resupply Subsystem. Its' operational interface with the combat crew is normally restricted to controls and displays within the crew compartment and the

refueling receptacles located on the vehicle exterior. Field maintenance requirements are limited to the initiation of diagnostic functions and filter changes, when appropriate. Normal maintenance activities may be conducted by 5th to 95th percentile soldiers, clothed in MOPP 4 gear or as necessary for the environment.

The following additional requirements are deemed necessary to ensure that the design and operation of the fuel system adheres to HFE guidelines as related to, but not limited to, work space anthropometry, controls and displays, labeling, system indicators, as well as providing accessibility for maintenance.

- Displays and controls related to the operation of the fuel system shall be concise and adequate for all lighting conditions.

- The externally mounted Hose Reel and Nozzle Assembly shall be readily accessible and operable by one dismounted soldier, clothed as necessary for the environment.

- No Module or component of the FARV Fuel System shall impede nor interfere with crew visibility during normal operation, docking or refueling.

- Under normal operating and refueling conditions, the fuel system shall not endanger the crew by exposure to toxic or flammable fumes or liquids, or to harmful noise or EMI emissions.

SECTION EIGHT

INTEGRATED LOGISTIC SUPPORT (ILS)

8.1 INTRODUCTION

ILS is defined, in AR 700-127, as the management process to facilitate development and integration of the twelve (12) individual logistic support elements to acquire, field and support a system. The Final Draft ORD and the Second Draft System Specification for the FARV fully identify and define the ILS requirements for the system. The purpose of this section is to expound on the ILS requirements, to the extent feasible, for the FARV Conceptual Fuel System.

8.2 REFERENCES

- AR 700-127; Integrated Logistic Support
- Final Draft Operational Requirements Document (ORD) for the Advanced Field Artillery System (AFAS) and Future Armored Resupply Vehicle (FARV)
- Second Draft Future Armored Resupply Vehicle (FARV) System Specification

8.3 MAINTENANCE

The ability to perform FARV Fuel System maintenance is limited by access to system componentry. Based on this, system componentry must consist of assembled components which have low failure rates, minimal maintenance requirements and a high MTBF.

8.3.1 Maintenance Management

The MMCS provides maintenance management and oversight for the Rearm/Resupply Sub-system as well as control of C3 and the Land Navigation Subsystems. The Rearm/Resupply Sub-system includes the components and mechanisms required to receive, store, transport and automatically up-load munitions, LP and fuel. The MMCS programming incorporates guidance and decision aids to assist the crew in the performance and successful accomplishment of these functions. These aids provide current and projected system status based on sub-system input.

The intelligence, consisting of program software/firmware, resident within the MMCS provides the crew with assistance in planning and making decisions applicable to a wide spectrum of mission related subjects, including, but not limited to:

- Total System Status and Subsystem Status

- o Inventory Management and Control
- o Sensing/Predicting of Equipment/Component Malfunction
- o Overriding of Automatic Functions/Procedures
- o Embedded Training
- o Diagnosing/Performing/Deferring Maintenance and BDAR Actions

8.3.2 Preventive Maintenance Checks and Services (PMCS)

PMCS actions required by the FARV Fuel System are minimal and reflect the ability of the MMCS to exercise the electrically operated components of the Fuel System and determine the status and/or result of each action. Normal PMCS actions will include the changing of filters and draining of water and sediment from filter/separator housings and fuel tank sumps at times when such activities will not jeopardize the FARV Mission.

8.3.3 Replacement of LRUs

To the extent feasible, the FARV Fuel System is designed to allow replacement of suspect or failed components without the requirement to loosen or remove adjacent parts or sub-assemblies.

8.3.4 Embedded Manuals

The MMCS includes, in its' programming, imbedded training aids which will duplicate hypothetical combat scenarios and equipment failure. In addition, operator and maintenance manuals are capable of being displayed at the system (MMCS) interface (control panel). This enables the crew to maintain the FARV in a Fully Mission Capable status.

8.4 SUPPORT STRUCTURE

The FARV will employ the four level maintenance concept consisting of Unit Level, Direct Support (DS), General Support (GS) and Depot Level. The Maintenance Allocation Chart (MAC) will specify the responsibilities for each level of maintenance.

8.4.1 Unit Level Maintenance

Unit level maintenance is performed at intervals recommended by FARV technical manuals. The MMCS monitors the status of the replaceable components, tracks usage and function and compares data to predetermined information to predict failure events.

8.4.2 DS Maintenance

DS maintenance will be performed by mobil maintenance support teams which diagnose and perform corrective maintenance actions in accordance with the MAC.

8.4.3 GS Maintenance

GS maintenance will perform commodity repair of components and end items. This consists of repair by component replacement, repair of components for replacement and repair of replaced components for return to the supply system.

8.4.4 Depot Level Maintenance

Depot level maintenance consists of the overhaul and repair of the end items, components and modules as well as repairs which exceed the capability of lower maintenance levels.

8.5 PERSONNEL AND TRAINING

The operators of the AFAS and FARV will have the same Military Occupational Specialty (MOS). FARV maintainers will undergo additional training for the maintenance and repair of the automated and electronic sub-systems. The MMCS will contain, within its programming, operator and maintenance training aids.

8.5.1 Personnel

8.5.1.1 FARV Operators

FARV operators are responsible for the performance of the primary FARV mission and all activities related to it, including but not limited to:

- The up-load of logistic supplies at the LRP
- The transport of munitions, LP and fuel to the AFAS resupply position
- The automatic transfer of munitions, LP and fuel to an AFAS or another FARV
- C3 activities
- Vehicle navigation
- PMCS actions as identified by the MMCS
- The down-load of logistics supplies as required to support maintenance actions.

8.5.1.2 Reduced Manning

The FARV has a normal crew compliment of three. It shall be capable of being operated for periods up to four hours with a crew of two. This capability allows the operating personnel to rotate through rest periods and maintain a high degree of readiness.

8.5.1.3 FARV Maintenance Personnel

FARV maintenance personnel are responsible for the periodic, scheduled, and emergency maintenance actions required by the FARV.

8.5.2 Training

Training applicable to the operation of the FARV Fuel System is minimal when compared to the available total system training available. The Rearm/Resupply Sub-system is automated to the extent possible by specification requirement and demands minimal guidance and participation by FARV operating personnel. Operator and maintainer training is preprogrammed within the MMCS.

8.5.2.1 System Embedded Training

The programming embedded within the MMCS includes individual and collective crew training applicable to mission operation and routine, as well as emergency, situations found on the battlefield. The embedded training can be used at any time but is prioritized in such fashion as to default to normal operation upon receipt of an operational command. The embedded training does not interfere with the normal conduct of resupply, transport, or docking and logistics transfer operations.

8.5.2.2 Operator Training

Operator training includes scenarios duplicating the probable conditions encountered in resupply, transport, docking, and logistic resupply of the AFAS or another FARV. The embedded training also displays the complete operators manuals upon request.

8.5.2.3 Tactical Simulation

Tactical simulations presented by the embedded training programming will duplicate system and component failures which might result from combat engagement.

8.5.2.4 Maintenance Training

Maintenance training for the FARV Fuel System includes electronic repair and trouble shooting as well as electro-mechanical system maintenance actions. The automation of the Rearm/Resupply Sub-system integrates a higher level of electronic components and servo-mechanisms into the vehicle than is found within similar Army combat vehicles. The embedded training simulates failure of these components and sub-systems and familiarizes the maintainer with the diagnostic capabilities of the MMCS.

8.6 SYSTEM INSPECTION, TEST, AND CLEANING

The FARV Fuel System is capable of being routinely inspected, tested, and serviced without the requirement to remove major assemblies or components.

8.6.1 Inspection

The FARV Fuel System is designed to permit periodic visual examination and inspection of the fuel fill receptacles and its manual and automatic fuel up-loading components. Inspection of the fuel tanks, valving, pumps and sensors is applicable only at maintenance level where the entire logistics supply load may be removed to permit access to inspection panels and covers.

8.6.2 Test

Testing of the FARV Fuel System is accomplished by directing the EEIM to exercise the various electrically energized components it directly, and indirectly, controls. The sensor feedback will confirm status of the modular components.

8.6.3 Cleaning

All componentry used in the assembly and fabrication of the FARV Conceptual Fuel System is immune to corrosion and adverse effects caused by exposure to petroleum based fuels, water and NBC decontamination chemicals. Cleaning of interior surfaces may be accomplished at any time it is deemed necessary. The MMCS, via the EEIM, monitors the status of the fuel tanks with regard to water/sediment build-up and recommends individual tank drainage on an "as required" basis. The actual time of drainage is as directed by the crew.

8.7 RELIABILITY, AVAILABILITY AND MAINTAINABILITY (RAM)

RAM, as applicable to the FARV Conceptual Fuel System, is an important consideration in the specification of components and fabricated parts. The majority of the Fuel Systems' componentry is inaccessible during the performance of a mission and must, therefore,

be capable of performing for extended periods of time with little, or no, maintenance. The choice and specification of Fuel System components is based on high RAM values.

8.7.1 Reliability

Component and modular MTBF is design limited to not less than 10,000 hours. The reliability of components is considered mission critical and, since accessibility to most features of the FARV Fuel System is limited, only proven components are acceptable.

8.7.2 Availability

The availability of FARV Fuel System components should not limit the effectiveness of the combat system. In order to maintain costs and inventories at acceptable levels, components should be readily available or maintained in repair facilities in numbers compatible to the need.

8.7.3 Maintainability

Component accessibility is limited in the FARV Conceptual Fuel System when it is in the field and employed in a combat environment. Therefore, all components are designed for ease of removal. No adjacent or connecting component need be loosened or removed to repair or replace a defective LRU. The majority of all fittings and connections in the FARV Fuel System are of the quick disconnect type or flanged to expedite removal. In addition, most of the componentry is "repaired by replacement" at the LRU level. The level of spare parts required to support the FARV is further minimized by commonality of components between modules.

SECTION NINE

SUMMARY AND RECOMMENDATIONS

9.1 SUMMARY

The FARV Fuel System is part of the Rearm/Resupply Sub-system of the FMM. The system is automated to the extent possible in order to attain control and logistic supply requirements. Automation of the system also enables the MMCS to monitor system performance, sense and/or predict equipment malfunction, assess battle damage, and perform inventory management.

The fuel system incorporates components necessary to enable refueling by SARS equipped LRPs, another FARV, and by manual means including various nozzles and "Jerry Cans". The system is designed to accept fuel at rates within the parameters established by SARS. The Fuel System is designed to accomplish the following:

- be refueled in less than two (2) minutes, at a rate of approximately 757 LPM (200 GPM), by SARS equipped refueling positions,
- be defueled using SARS equipment in less than four (4) minutes, at a rate of approximately 378.5 LPM (100 GPM),
- refuel an AFAS or another FARV at a rate of 190 LPM (50 GPM),
- transfer fuel from tank to tank, or off-board via the SARS, at 190 LPM (50 GPM), and
- defuel another vehicle equipped with a SARS type receptacle at a rate of approximately 190 LPM (50 GPM).

9.2 RECOMMENDATIONS

The following recommendations reflect the developmental status of the FARV/AFAS concept as well as the parameters governing the design of the FARV Fuel System.

- The FARV Fuel System design is a victim of sub-system prioritization. Without fuel the FARV and AFAS cannot reach tactical points to fulfil mission requirements. It is recommended that the fuel system assume the same level of priority as the munitions and LP.

- It is recommended that the FARV have an additional amount of fuel allocated to it for its own fuel reserve. This will ensure that the FARV can return to the LRP from distances more reflective of a battle situation which may necessitate moves of 5-10 km at a time during combat advances.

- It is recommended that the algorithm used to define the number of AFAS resupply actions be altered to reflect a specific percentage of logistic material consumed, rather than "upon every move". Thereby increasing the survivability of each unit by maintaining a visually smaller target profile and by reducing the total number of km traveled by the FARV. This would reduce maintenance requirements, increase the projected service life of the Rearm/Refuel Sub-systems by not requiring them to be activated to transfer less than a certain quantity of logistic load (e.g., 15%-20%).

- It is recommended that consideration be given to the separation of the control of the munitions and LP mechanisms from the MMCS, as is the EEIM for the fuel system. The C3 activities that will be conducted by the MMCS may be incumbered if control of automation is required. Like the fuel system control components, it is likely that the robotic system will also require components which create and emit EMI, and it will be deleterious to the MMCS to co-locate such components in close proximity to the prerequisite integrated circuitry. Distance, alone, can reduce the effect of EMI and will also reduce the weight (thickness) of the shielding required to protect some micro-circuits and processors.

- It is unlikely that the weight limitations can be met and still retain the characteristics reflected by the Performance Specification. It is recommended that limiting the vehicular ground pressure would be more applicable.

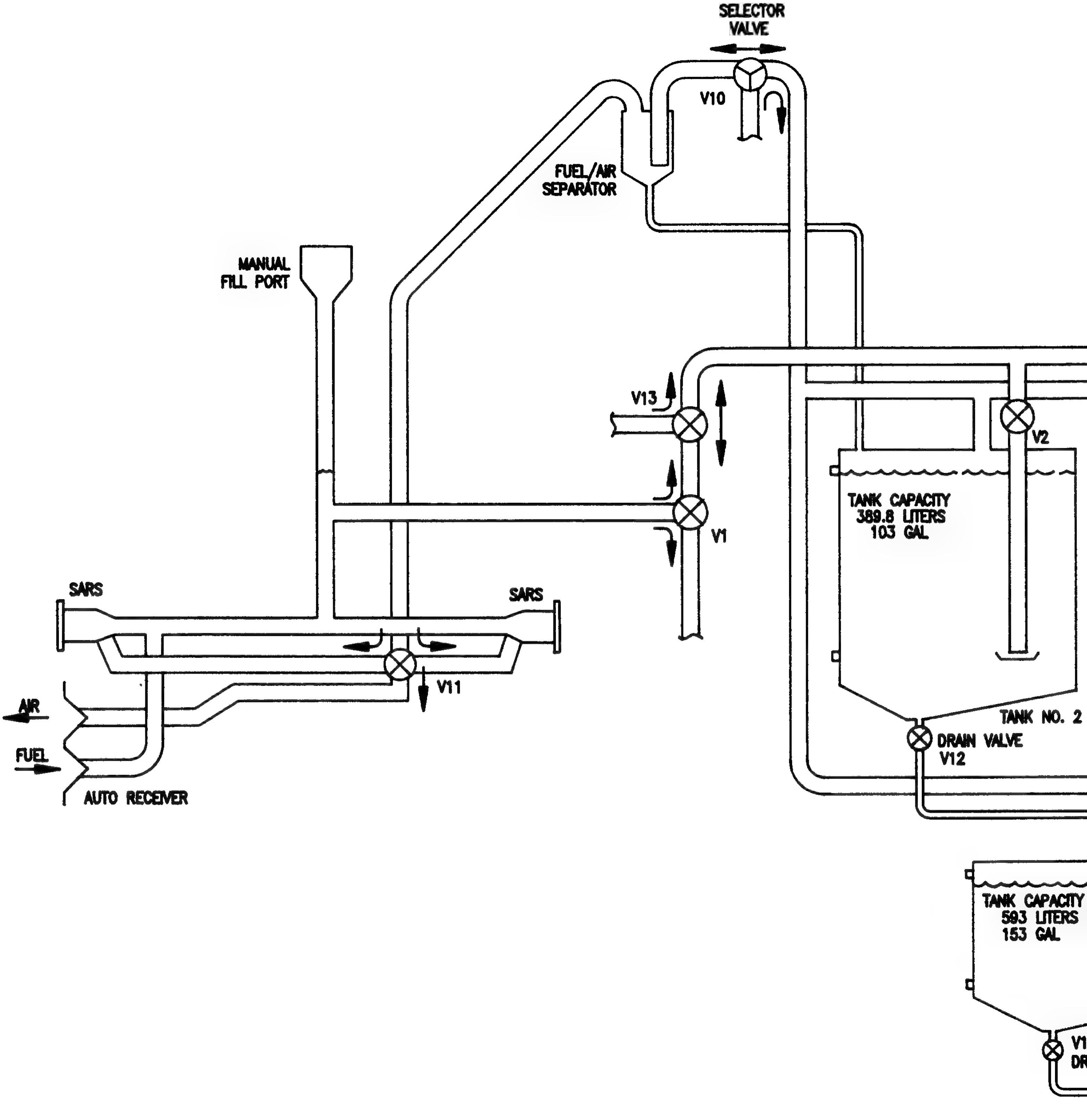
- The recommended FARV Fuel System contains COTS and NDI fuel handling components. Should weight be of primary importance, it is recommended that the valves, pumps, separators and sensors be custom fabricated from ultra-light alloys which still meet the corrosion and exposure limitations of the specification. The weight of the Fuel System (minus fuel) could be significantly reduced if COTS and NDI componentry were replaced by custom fabrications.

- The complexity of the automatic system for logistic resupply is such that definitive and conscious decisions must be made for each sub-system that will deleteriously affect related, or interfacing, sub-systems. It is recommended that additional study and analysis be undertaken which explores the development of the automatic logistic resupply of munitions, LP and fuel as one system.

APPENDIX A

PROOF OF CONCEPT

COMPUTER MODEL DEVELOPED FOR THE FARV FUEL SYSTEM



SARS/FARV FUEL

NOTES:

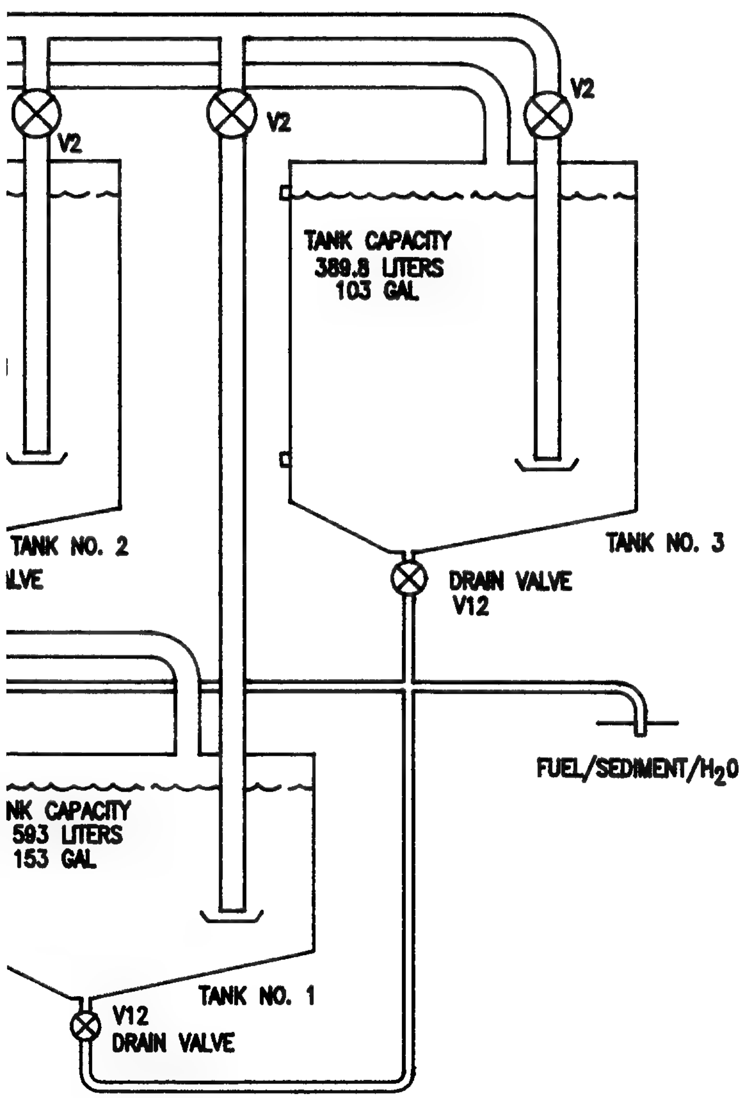
1. VALVE OPERATION SHALL BE AS FOLLOWS:

   A. 4-WAY SELECTOR VALVES

POSITION 1	TANK NO. 1
POSITION 2	TANK NO. 2
POSITION 3	TANK NO. 3
POSITION 4	CLOSED

   B. 3-WAY SELECTOR VALVES

POSITION 1	APS
POSITION 2	MAIN ENGINE
POSITION 3	BOTH



= FUEL SYSTEM VENT PIPING

= FUEL SYSTEM FUEL PIPING

= P/O FUEL TRANSFER MODULE

UEL SYSTEM

DEVELOPMENT AND OPTIMIZATION OF A COMPUTER MODEL OF THE FARV FUEL SYSTEM

REPORT DATE: OCTOBER 31, 1994

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UNDER CONTRACT NO. DAAK70-92-D-0004
TASK ORDER 0130

Development and Optimization of a Computer Model of the FARV Fuel System

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Development and Optimization of a Computer Model of the FARV Fuel System

1.0 INTRODUCTION.

Under the Radian Inc. Purchase Order No. 12129, dated 15 September 1994, VSE was tasked to develop and optimize a SINDA/FLUINT computer model of the FARV fuel system proposed by the engineers at Radian. This fuel system is detailed in the 30 September 1994 draft report entitled Final Report Future Armored Resupply Vehicle (FARV) Conceptual Fuel System Design (Report No. RADIAN/94/0130). Specifically, under the aforementioned Purchase Order, VSE engineers were expected to:

(1) develop a working SINDA/FLUINT model of all Fuel Storage Module (FSM) fuel and vent (vapor recovery) lines;
(2) adjust FSM line sizes to meet mission requirements (i.e. 2 minute refueling of FARV by SARS); and,
(3) investigate FSM valve closure and valve selection as possible causes of pressure spikes and suggest corrective action.

2.0 PURPOSE.

The purpose of this report is to document the work performed by VSE engineers in optimizing the proposed FARV FSM design.

3.0 SCOPE.

The scope of this report is limited to the following:

(1) a discussion of the development of the SINDA/FLUINT model and the underlying assumptions;
(2) a discussion of the SINDA/FLUINT analysis regarding resizing FSM lines to meet the 2 minute fueling time; and,
(3) a discussion of the SINDA/FLUINT analysis regarding altering valve closure rates or changing valve selection to minimize pressure spikes.

4.0 DEVELOPMENT OF THE SINDA/FLUINT MODEL.

4.1 System Configuration.

Technical report Radian/94/0130 details the geometry currently proposed for the FSM. From the illustrations in Appendix A of that report, fitting orientations were inferred. Appendix B of the same report provides vendor data regarding components anticipated for incorporation into the FSM. VSE Engineers contacted the vendors suggested in Appendix B of Radian/94/0130 to determine loss factors for the "refuel/defuel valve" (N8 in Radian/94/0130 Appendix A, page A-2) and the tank "shut-off valves" (N12, N13 and N14 in Radian/94/0130 Appendix A, page A-2). These loss factors are summarized below.

Refuel/Defuel Valve (N8)	Size=2"; 3-Way ball valve; L-type.	Cv=120 gpm[1]
Shut-off Valves (N12, N13, N14)	Size=2"; 2-Way ball valve.	Cv=200 gpm

4.2 The SINDA/FLUINT Model.

In general, SINDA/FLUINT fluid submodels are comprised of 'lump' and 'path' elements. Lump elements can be used to model control volumes, system nodes and plena. Path elements dictate the losses along fluid lines and the anticipated significance of fluid inertial effects. Therefore, to exactly predict the performance of physical fluid systems, each system line/component should be represented by a collection of appropriately connected lump and path elements.[2] However, it is both analytically difficult and computationally expensive to develop and run exacting SINDA/FLUINT component models. As a result a number of engineering approximations have been made to facilitate this analysis (detailed below).

The SINDA/FLUINT model 'FARVFUEL' is comprised of two fluid submodels named 'FUEL' (FSM fuel lines) and 'VAPOR' (FSM vent liens). For this analysis, water (per ASHRAE 718) is the working fluid in the fuel lines and air, as an ideal gas, is the working fluid in the vent lines.[3] The 'FARVFUEL' ASCII model file is provided in Appendix A of this report.

4.2.1 FSM Fuel Lines.

The 'FUEL' submodel schematic is provided in Figure 1. The following discussion will trace the fuel path through 'FUEL' (from inlet to outlet) and detail the assumptions underlying its construction.

---

[1] Cv is the flow rate through a hydraulic fitting which results in a pressure drop of 1 psi for a flow at 60 degrees Farenheight.

[2] An accurate representation of a garden hose would consist of a large number of infinitesimal lumps and paths. The lumps account for the instantaneous amount and distribution of the liquid in the hose. The paths account for the losses and inertial effects associated with the motion of the fluid along the hose.

[3] It is anticipated that the prototype FARV fuel systems will be tested using water and air as the working fluids.

Typically, the FARV FSM will be refueled by military tankers via the SARS connection. In Figure 1, plenum (P-1) represents a generic military tanker that will refuel the FSM via a 'Fictional Pump'. Throughout this analysis, it will be assumed that refueling is accomplished via the FARV starboard SARS port.

The performance of the 'Fictional Pump' is established as follows:

(1) assume that the tanker's 'Fictional Pump' has a performance curve which can be represented mathematically by (Q-Qo)=-0.00928*(H)**2,
where
Qo=pump flow rate as head approaches 0.0 feet;
(2) making the further assumption that the pump exhibits peak efficiency at 175 gpm and 115 feet head (this corresponds to a pump outlet pressure of 35 psig) Qo=297 gpm.

For simplicity, it will be assumed that the transient effects associated with pump startup are negligible.

In submodel 'FUEL', the SARS nozzle is designed to regulate the its outlet pressure to a minimum value of 14 psig.[4] For the purposes of this analysis, the SARS nozzle/receptacle is configured to shut down the flow, in a linear fashion, as its outlet pressure grows from 25 psig to 30 psig. When the SARS nozzle/receptacle outlet pressure initially attains a value of 25 psig, the corresponding mass flow through the SARS is recorded. The value '25 psig' was chosen after observing that refueling simulations performed *without* the receptacle component model exhibited SARS back pressures in excess of 25 psig as the tanks became filled.

The shut-off valves (N12, N13, and N14) were modeled using SINDA/FLUINT 'control valve' elements. As each tank reaches 95% of capacity, the corresponding upstream shut-off valve instantaneously closes. This ensures that the observed pressure spikes will represent a worst case scenario for the system.

Loss factors for all standard fittings (e.g. tees and elbows) were approximated by referring to Cameron Hydraulic Data (Copyright 1977 by Ingersoll-Rand Company, editors Westway and Loomis).

As for the FSM fuel lines themselves, the baseline configuration employs 2" diameter lines having a uniform roughness of 6.0E-5" (i.e. drawn/extruded tubing). The fluid volume associated with

---

[4] Actual SARS nozzles regulate the flow pressure to values between 14 and 22 psig. Regulation pressures of 14 psig present the worst case scenario for achieving 2 minute refueling.

all fittings and 'short' (less than 25" in length) pipes/tubes was assumed to have a negligible impact on system performance. On the other hand, fluid volumes associated with 'long' (over 25" in length) pipes/tubes are modeled by associating half the total pipe/tube fluid volume with each end of the corresponding path.

4.2.2 FSM Vent Lines.

The 'VAPOR' submodel schematic is provided in Figure 2. Submodel 'VAPOR' is considerably less well defined than 'FUEL'.

There appears to be little documentation available regarding loss factors through standard pneumatic fittings (e.g. elbows and tees). Consequently, VSE Engineers fell back on Cameron Hydraulic Data to prescribe the loss factors employed in 'VAPOR'. It is expected that these values will significantly overestimate the resistance to flow offered by the vent lines; and, as a result, simulation results will likely indicate a refueling time that is greater than what will be experienced in the new physical system.

In the baseline configuration, nearly all lines have a 2" hydraulic diameter (circular section). Again, the wall roughness is that of extruded tubing (6.0E-5").

Because the density of air is much less than that of water, it was decided to neglect gravitational effects in 'VAPOR'. The fluid volumes associated with the vent lines were neglected for the same reason.

4.2.3 Linkage Between 'FUEL' and 'VAPOR'.

SINDA/FLUINT Version 2.6 requires that only one working fluid be associated with each fluid submodel.[5] Therefore, when *physical tanks* contain both liquid and gas two SINDA/FLUINT fluid submodels must be employed:

(1) a submodel where gas is the working fluid and a SINDA/FLUINT 'tank' element is used to represent the amount of gas in the physical tank; and,

(2) a submodel where liquid is the working fluid and a SINDA/FLUINT 'tank' element is used to represent the amount of liquid in the physical tank.

To accomplish the linkage between 'FUEL' and 'VAPOR' one must realize the following:

(1) the volume of the SINDA/FLUINT 'tank' elements in 'VAPOR' decreases according to the mass flow rates of fuel into the 'tank' elements in 'FUEL' (i.e. $VDOT_{vapor\ tank}$=-1.0*$FR_{into\ fuel\ tank}/DL_{fuel\ tank}$);

(2) the volume of the SINDA/FLUINT 'tank' elements in 'FUEL'

---

[5] Version 3.0 overcomes this shortcoming.

increases according to the mass flow rates of vapor exiting the 'tank' elements in 'VAPOR' (i.e. $VDOT_{fuel\ tank}=FR_{exiting\ vapor\ tank}/DL_{vapor\ tank}$;
(3) the compliance 'seen' by the 'tanks' in 'FUEL' is due to the compressibility of the gas in the 'VAPOR'; and,
(4) assuming the liquid is incompressible, the compliance 'seen' by the 'tanks' in 'VAPOR' is zero.

5.0 FSM OPTIMIZATION.

5.1 Objectives.

As previously stated, the baseline FSM configuration employed extruded steel tubing having a hydraulic diameter of 2" (circular section). FSM optimization is aimed at:

(1) minimizing FARV refueling times using SARS;
(2) minimizing pressure spikes in FSM lines due to valve closures; and,
(3) minimizing FSM weight (i.e. section size).

Because 'optimization' of the FSM configuration to achieve any one of these three objectives typically results in a FSM configuration that is not optimized with respect to the remaining objectives, certain trade-offs will require consideration before an 'optimal' FSM configuration can be recommended.

5.2 Technical Approach.

To initiate a discussion of 'optimal' FSM configurations, a significant amount of simulation data regarding FSM performance is required. First, FSM baseline configuration simulation results are presented. Next, simulation results predicting the impact of uniformly changing 'VAPOR' line sizes are provided. Finally, the effects of selectively resizing 'FUEL' lines are considered.

5.3 Baseline Simulation Results (Run 1).

Figure 3 shows 'FUEL' 'tank' volumes as a function of time. Note that this simulation took 108 seconds for all FARV tanks to fill.

Figure 4 shows 'VAPOR' 'tank' volumes as a function of time. This plot verifies that the 'FUEL'-'VAPOR' submodel linkage is functioning properly (i.e. at all times the sum of the volumes of the corresponding 'FUEL' and 'VAPOR' 'tanks' is equal to the capacity of the physical tanks).

Figures 5 and 6 show the 'tank' pressures for 'FUEL' and 'VAPOR' during refueling. Although, these plots do not match exactly on a quantitative basis, the qualitative trends demonstrated in these plots reassure the user that the 'FUEL'-'VAPOR' submodel

linkage is functioning properly.[6]

Figure 7 details mass flow rates through the shut-off valves in 'FUEL'. Note that side tank 1 ('a') fills first, side tank 2 ('b') fills second and the center tank ('c') fills last. Plot line 'c' does not drop to 0.0 at shut-off because the simulation terminates when the mass flow in 'FUEL' becomes 0.0.

Figure 8 shows worst case pressure spikes due to *instantaneous* shut-off valve closure. Notice that, in no case do valve closures result in pressure spikes in excess of 4 psid.

Figure 9 illustrates SARS inlet ('a', identical to pump outlet), regulation point ('b', 14 psig) and outlet pressures ('c', controlled by receptacle performance) as a function of time.

Figure 10 is a blow-up of SARS outlet pressure as a function of time. Because the SARS outlet pressure (backpressure) never achieves 30 psia, the nozzle/receptacle never shuts down the flow.

Figure 11 depicts mass flow through the pump as a function of time. To minimize refueling times, pump mass flow rates must be maximized during refueling.

Figure 12 shows the division of mass flow at the refuel/defuel valve.

Figure 13 shows the division of mass flow downstream of the refuel/defuel valve at a tee fitting which leads to side tank 2 and the center tank.

Note: *The baseline configuration is expected to meet the 2 minute FARV refueling requirement.*

5.4 Optimizing the FSM Vent Lines.

With the expectation that the SINDA/FLUINT submodel 'VAPOR' provides a conservative representation of the baseline FSM vent lines, it was hoped that 'VAPOR' could be optimized with respect to concerns about FSM weight.

Run 2. The first attempt made to reduce the weight of the FSM vent lines entailed modifying the 'VAPOR' submodel to use lines having a hydraulic diameter of 1/2". For simplicity, it was assumed that the loss factors used to model 'VAPOR' fittings in

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[6] The reason for the quantitative mismatch is due to the size of the timestep used in the simulation. However, because these inaccuracies are on the order of 0.01 psia, they are unlikely to adversely affect simulation results.

the baseline configuration (2" hydraulic diameter) would not change significantly. Figures 14-16 illustrate simulation results using 1/2" vent lines. It is clear from Figure 15 (which shows 'FUEL' 'tank' volumes as a function of time) that such a system will not be capable of meeting the 2 minute FARV refueling prerequisite (i.e. only side tank 1 has filled). Figure 15 shows 'FUEL' 'tank' pressures as a function of time, and Figure 16 shows pressure spikes at the shut-off valves due to closure of CT-9 (the shut-off valve upstream of side tank 1).

Run 3. A second attempt to minimize the weight of the FSM vent lines involved changing the hydraulic diameter of the FSM vent lines to 1". Figures 17-19 provide the same information as Figures 14-16 for 1" FSM vent lines. This time, refueling is accomplished in approximately 116 seconds. However, from Figure 17, it is evident that side tank 1 fills much more quickly than either side tank 2 or the center tank. Figure 18 shows that the tanks reach a maximum pressure of less than 1 psig (FARV fuel tanks are expected to be capable of withstanding 3-5 psig). Finally, Figure 19 demonstrates that the maximum pressure spike (3.5 psid) will occur at the shut-off valve upstream of side tank 2.

5.5 Optimizing FSM Fuel Lines.

Thus far it has been demonstrated that an FSM configuration employing 1" vent lines will permit 2 minute FARV refueling times with maximum pressure spikes (due to valve closure) of approximately 3.5 psid. At this point, it seemed appropriate to investigate the feasibility of minimizing the weight of the FSM fuel lines.

Run 4. Noticing that side tank 1 fills much more quickly (in each of the aforementioned simulations) than either side tank 2 or the center tank, 'FUEL' was modified so that, downstream of the refuel/defuel valve, line sizes leading to side tank 1 were reduced to 1.5" (hydraulic diameter). For this simulation, the loss factors associated with the fittings along the 1.5" lines were adjusted per Cameron Hydraulic Data. Figures 20, 21 and 22 illustrate tank volumes, tank pressures and shut-off valve pressure spikes, respectively, as a function of time. For this simulation, all FARV tanks fill over the same period (approximately 111 seconds). Again, tank pressures remain below 1 psig; and, pressure spikes remain below 4.5 psid.

Run 5. Figures 23-25 describe tank volumes, tank pressures and shut-off valve pressures for a system having:

(1) 1" vent lines;
(2) 1.5" lines between the refuel/defuel valve and side tank 1; and,
(3) 1.5" lines between tee N9 (tee N9 splits the fuel path between side tank 2 and the center tank) and side tank 2.

It should be noted that all 'FUEL' fittings are IAW Cameron Hydraulic Data. For this simulation, refueling was completed in approximately 120 seconds and the maximum pressure spike due to shut-off valve closure was 6 psid.

Run 6. Since it was observed that decreasing vent line sizes increases refueling times one last simulation was performed. The SINDA/FLUINT model was identical to that used in Run 4 except that the FSM vent lines had a hydraulic diameter of 1.5". Figures 26-32 provide a relatively complete description of FSM performance. For this scenario, FARV refueling was completed in 109 seconds (approximately) and pressure spikes remain below 3.5 psid.

6.0 CONCLUSIONS AND RECOMMENDATIONS.

6.1 Conclusions.

It is concluded that the analysis documented herein makes a good 'first effort' regarding the optimization of the FARV FSM.

Reducing FSM vent line sizes results in increased refueling times and higher tank pressures during refueling.

Reduction of FSM fuel line sizes results in larger pressure spikes due to shut-off valve closures. However, it appears unlikely that pressure spikes due to shut-off valve closures will pose a significant problem with respect to FSM performance. After all, even instantaneous valve closures were incapable of producing pressure spikes in excess of 6 psid for the various configurations detailed above.

It should be noted that theoretical data rather than empirical data was used to model the following components:

(1) pump performance;
(2) SARS flow regulation; and,
(3) fittings used in the FSM vent lines.

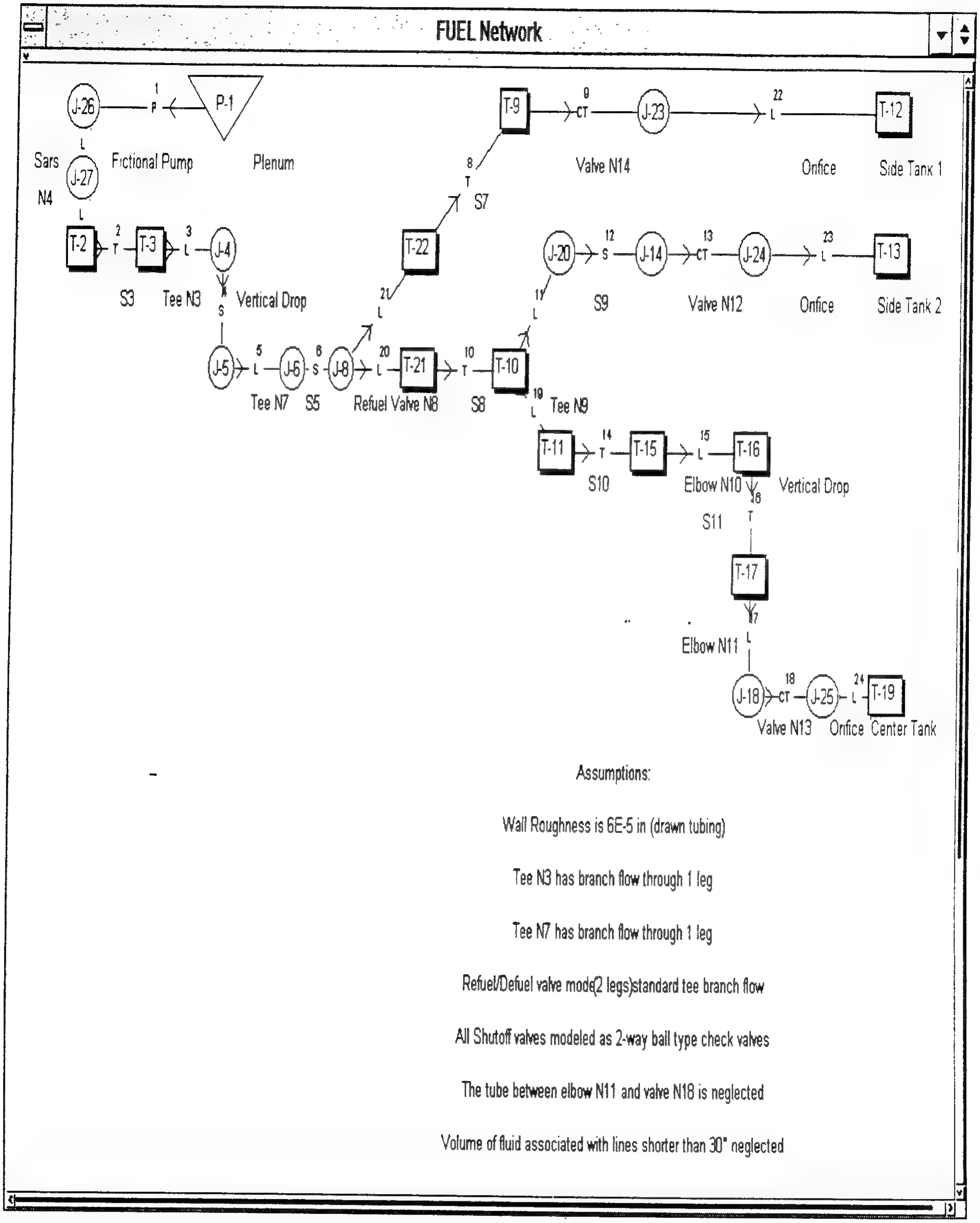
The results of Run 4 indicate that FSM weight can be reduced from the baseline configuration without significantly increasing FARV refueling times or FSM pressure spikes.

6.2 Recommendations.

It is recommended that further simulation be conducted when test data is available for key components as follows:

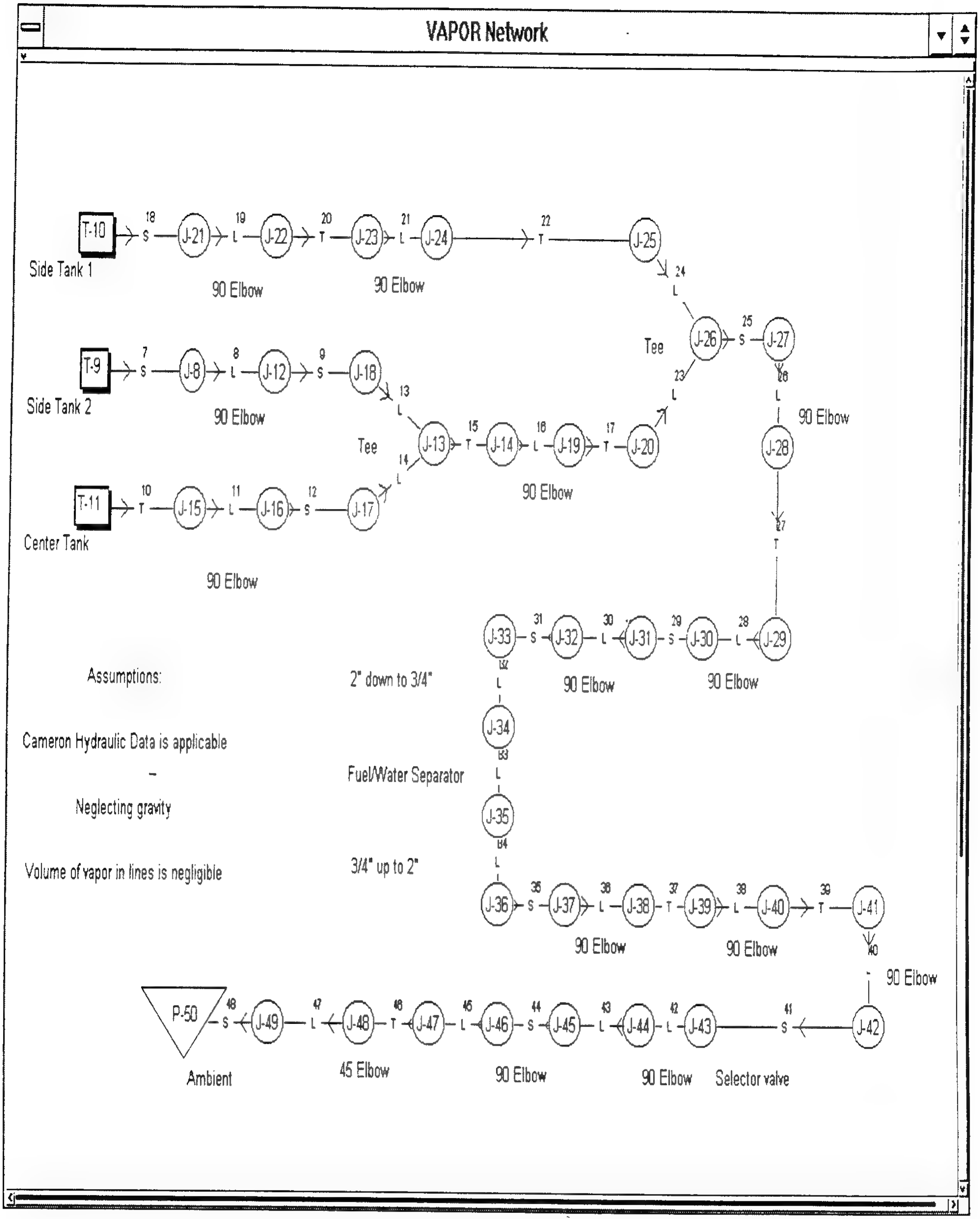
(1) refueling pump performance;
(2) SARS nozzle/receptacle performance;
(3) losses in vapor line fittings;
(4) actual shut off valve closure rates should be added to

the SINDA/FLUINT simulation file; and,
(5) further parametric analyses/simulations should be performed to identify FSM configuration trade-offs with respect to weight reduction, pressure spikes and the minimization of refueling periods.



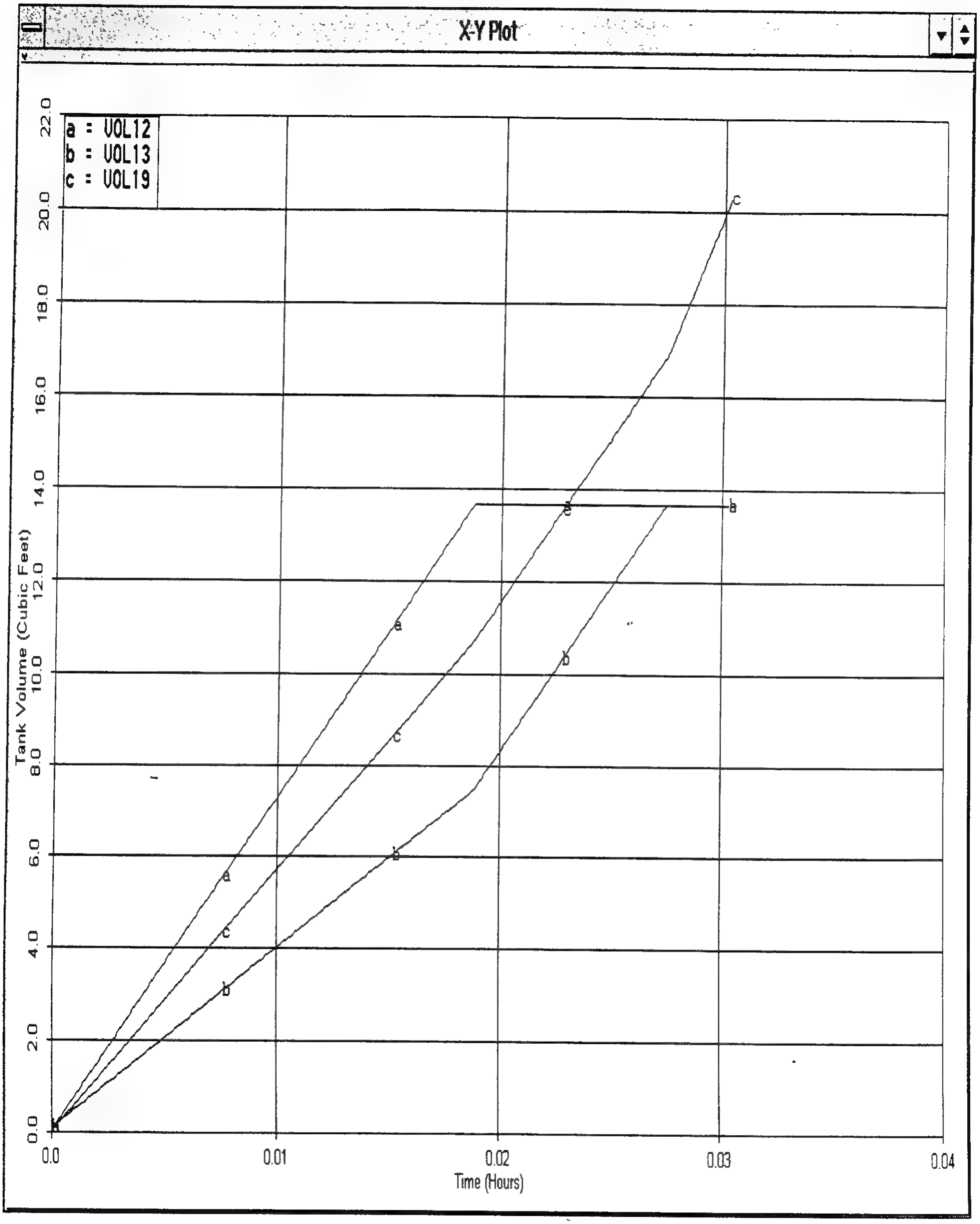
Fuel Side Scheme

Figure 1



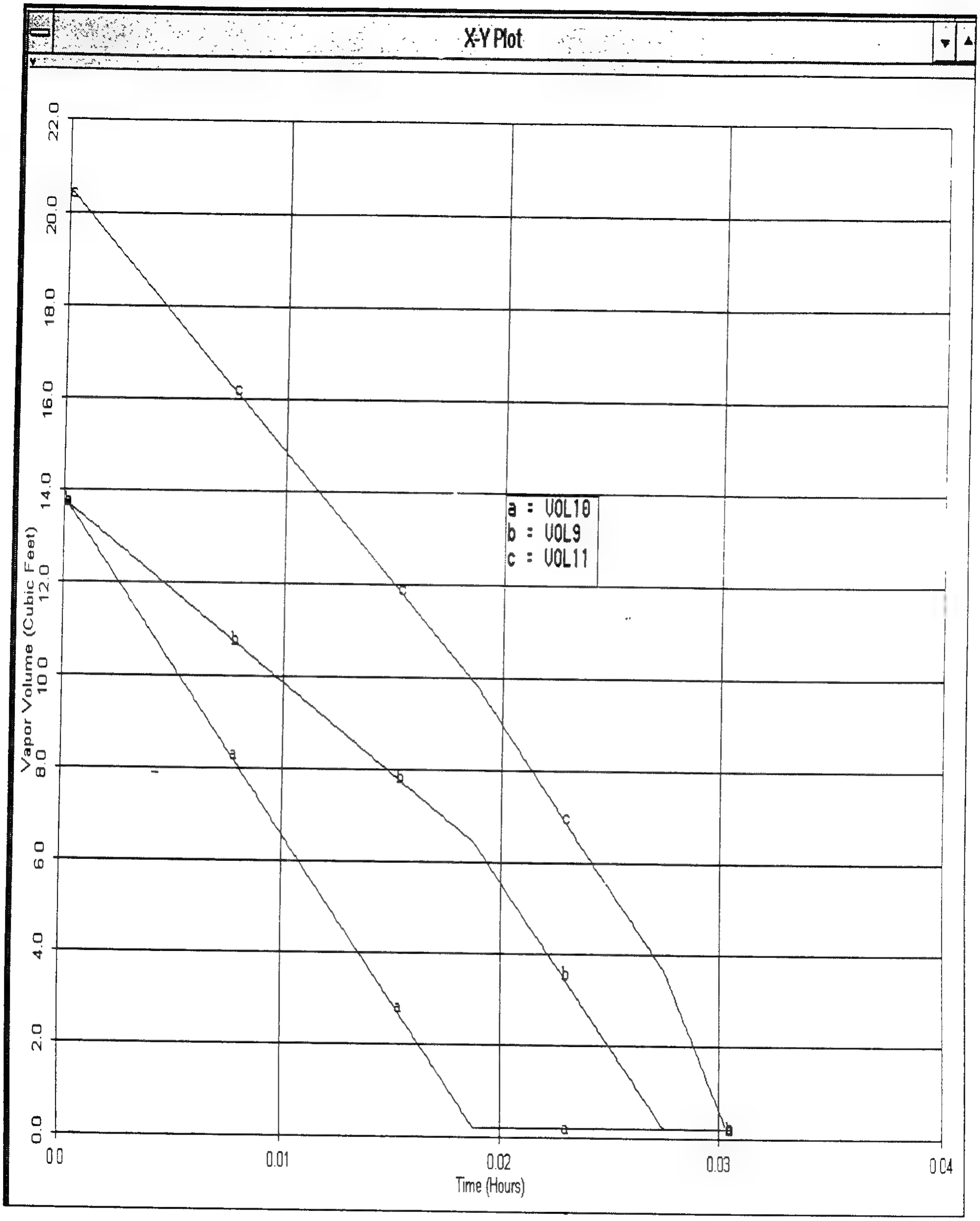
Vapor Side SCheme

Figure 2



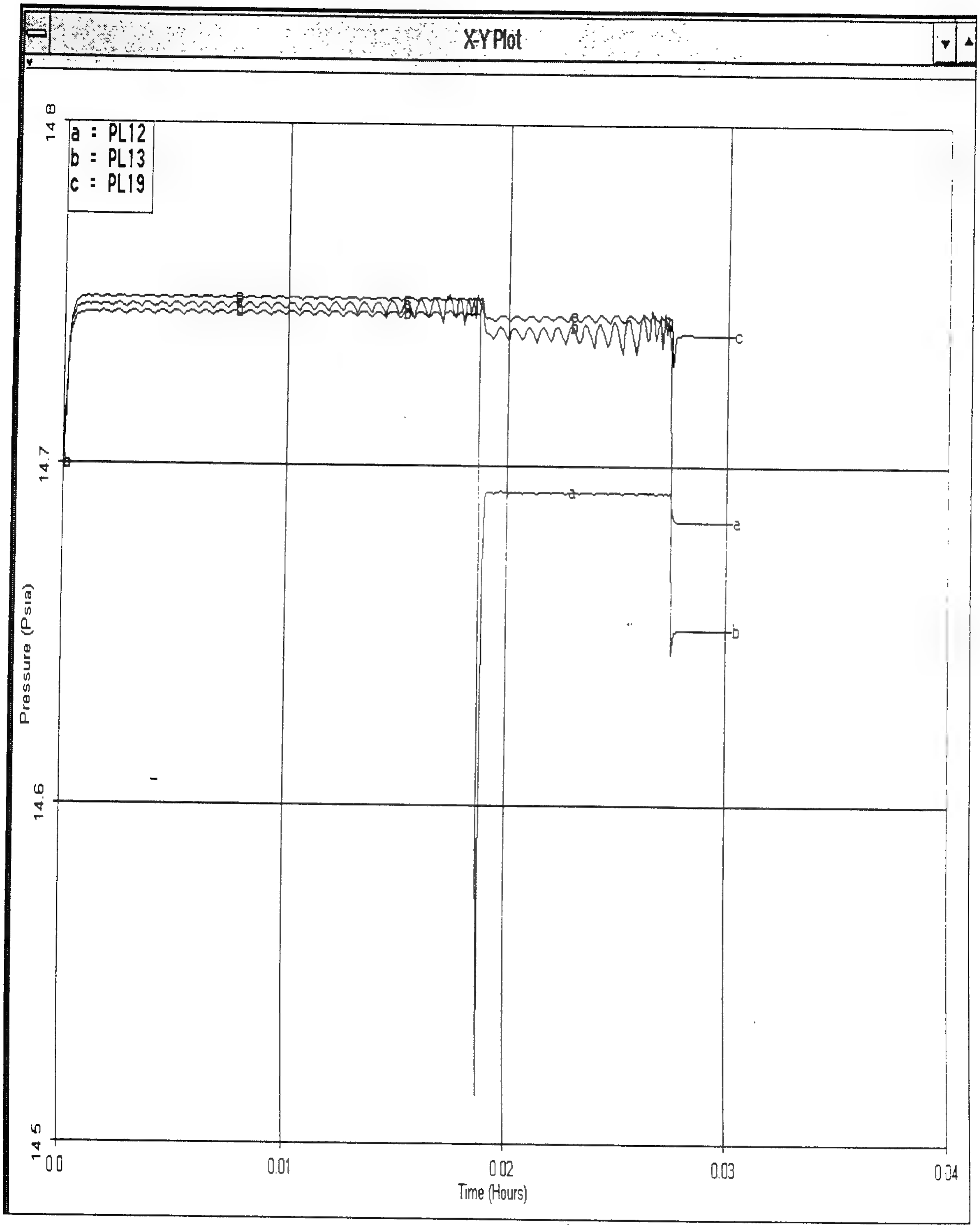
Fuel Tank Volumes as a Function of Time (a and b are side tanks, c is the center tank)

Figure 3



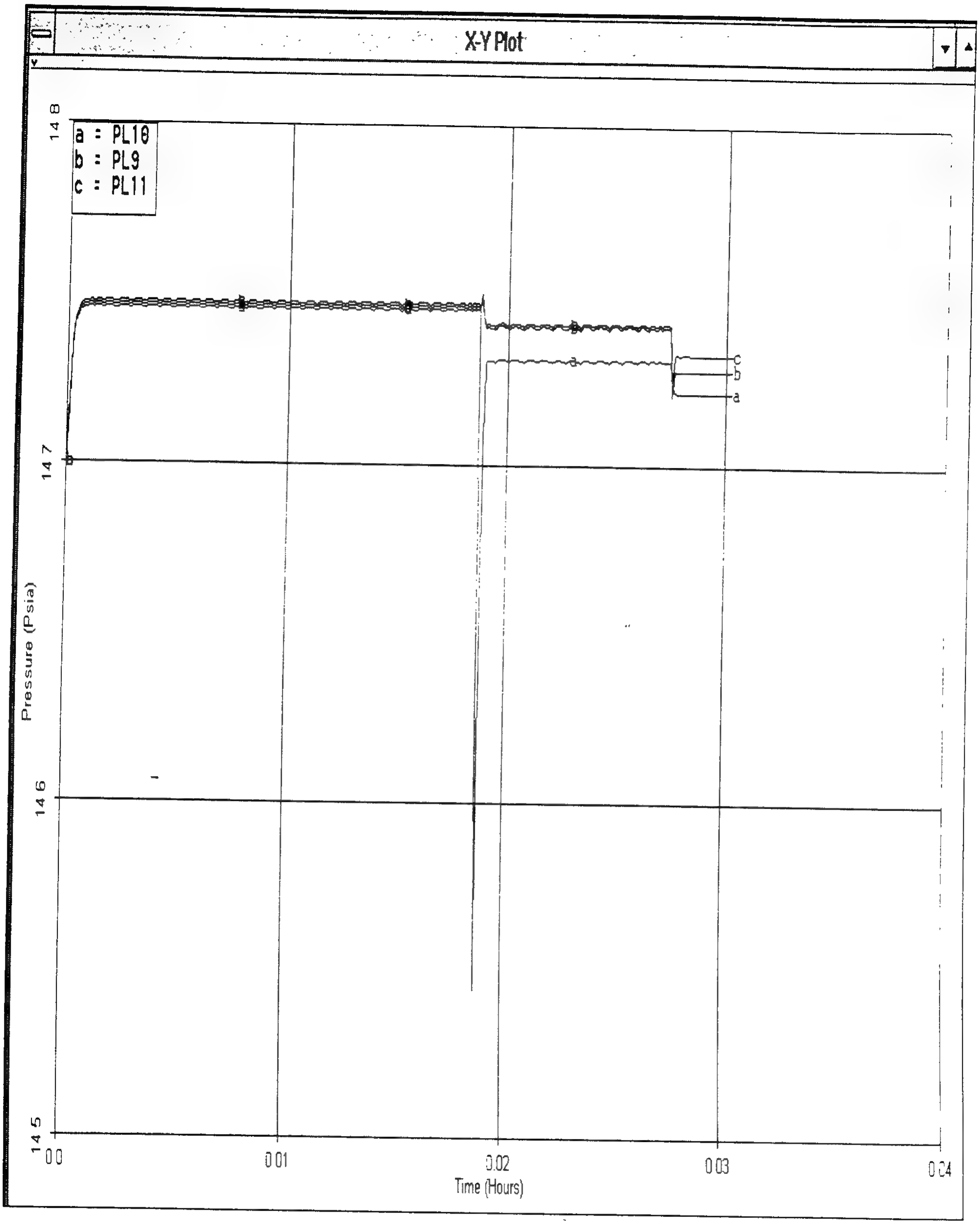
Vapor Leaving Fuel Tanks Over Time (a and b are side tanks, c is the center tank)

Figure 4



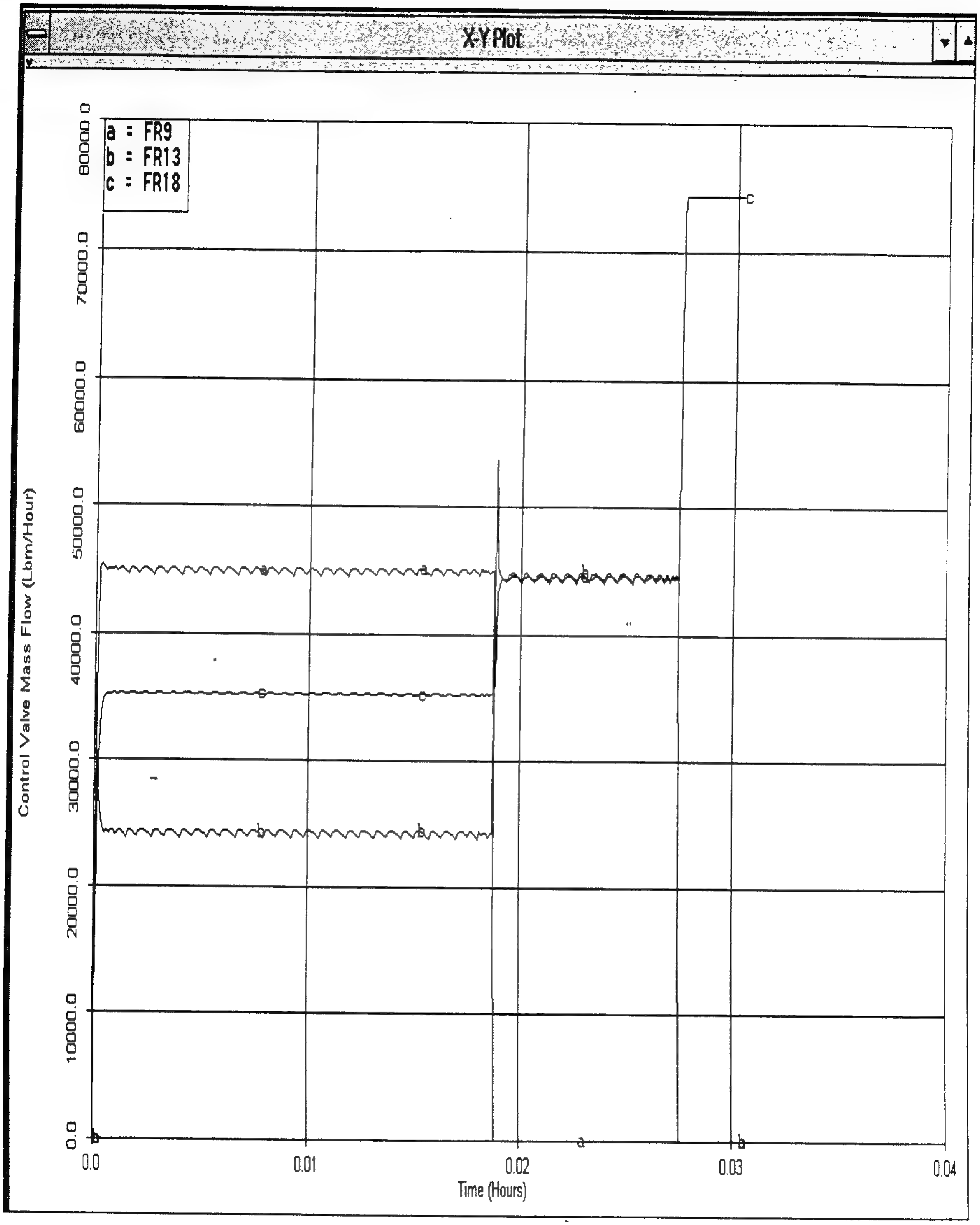
Pressure in Fuel Tanks During Refueling (a and b are side tanks, c is the center tank)

Figure 5



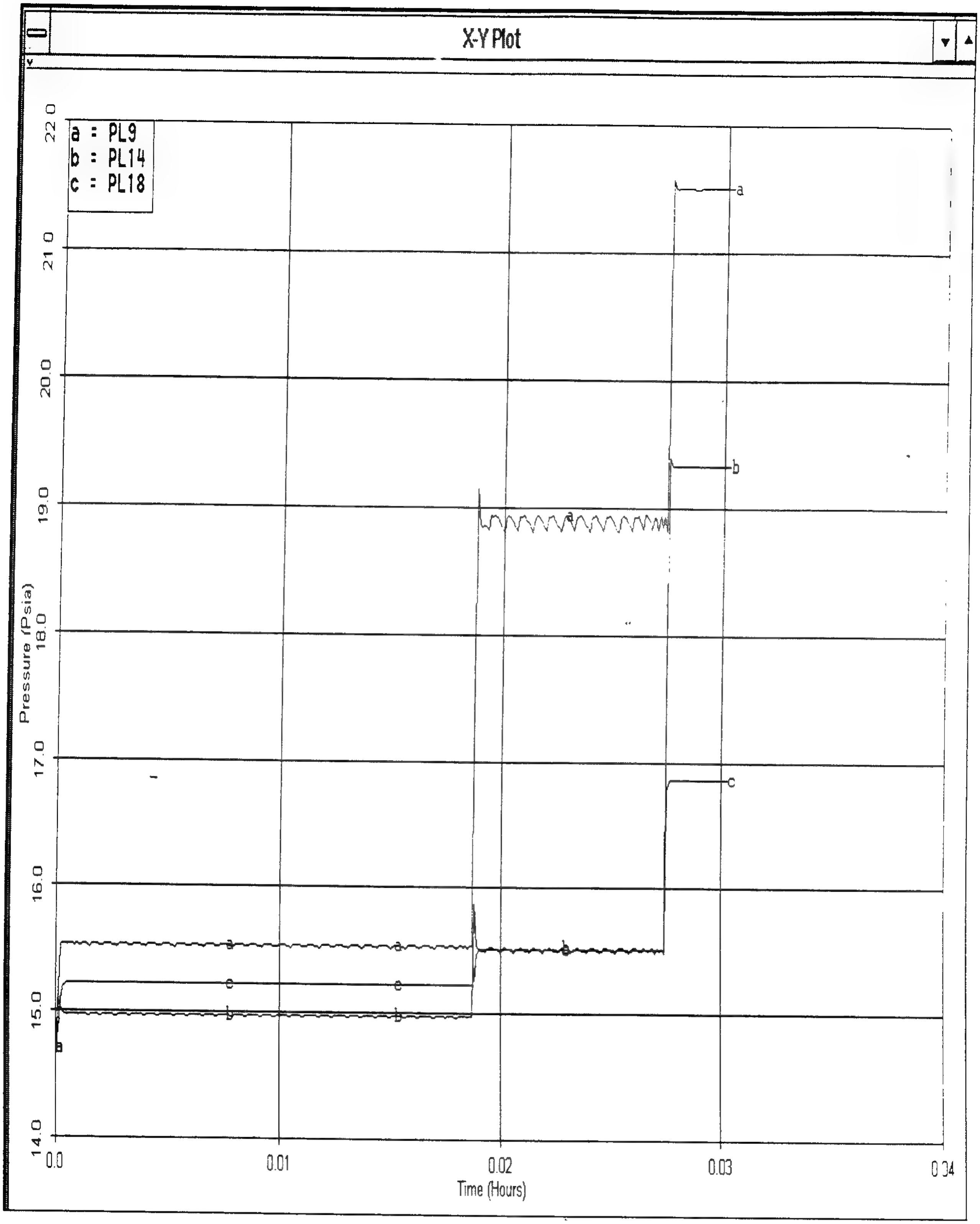
Pressure of Vapor in Tanks During Refueling (a and b are side tanks, c is the center tank)

Figure 6



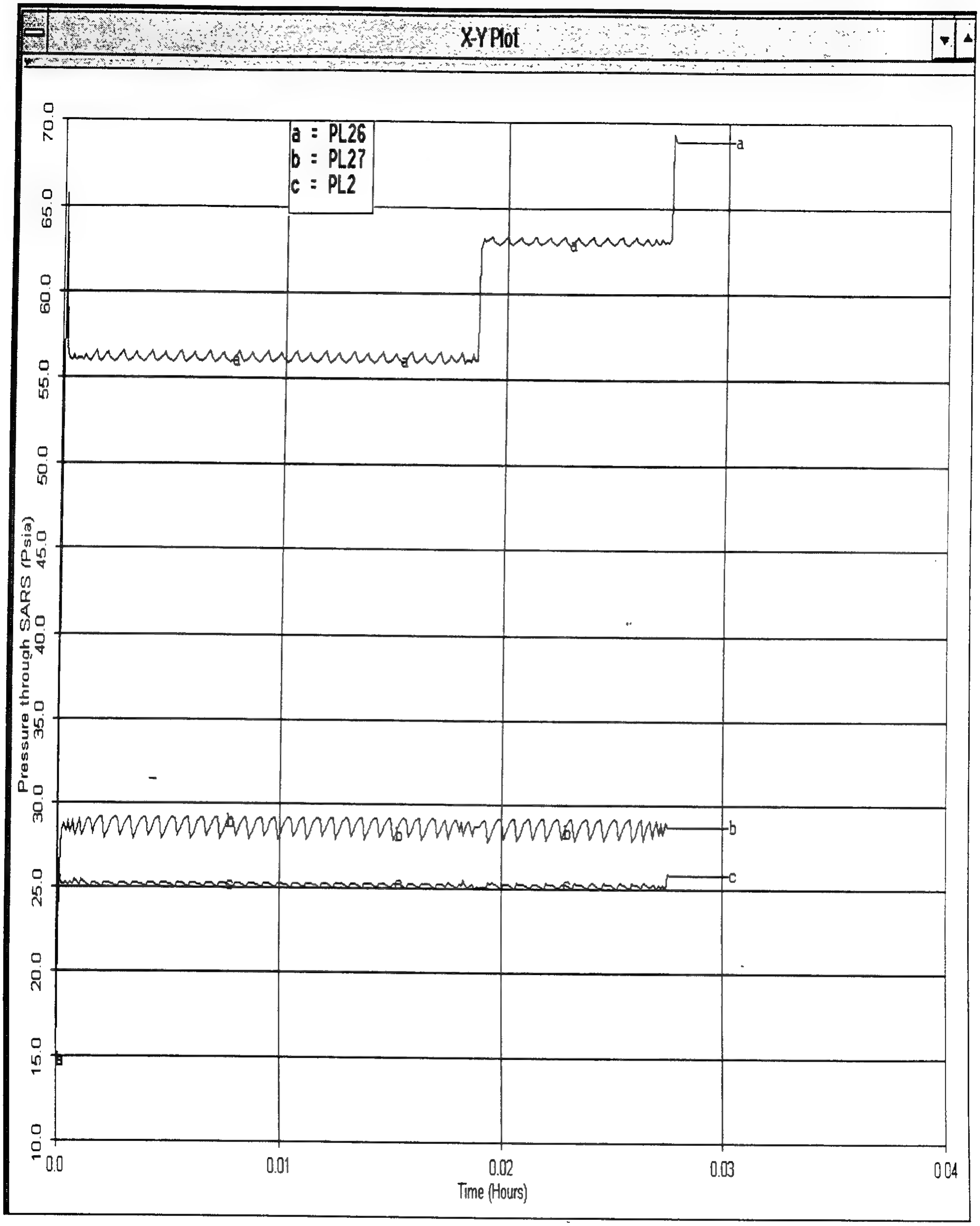
Shut Off Valve Performance (a and b are side tanks, c is the center tank)

Figure 7



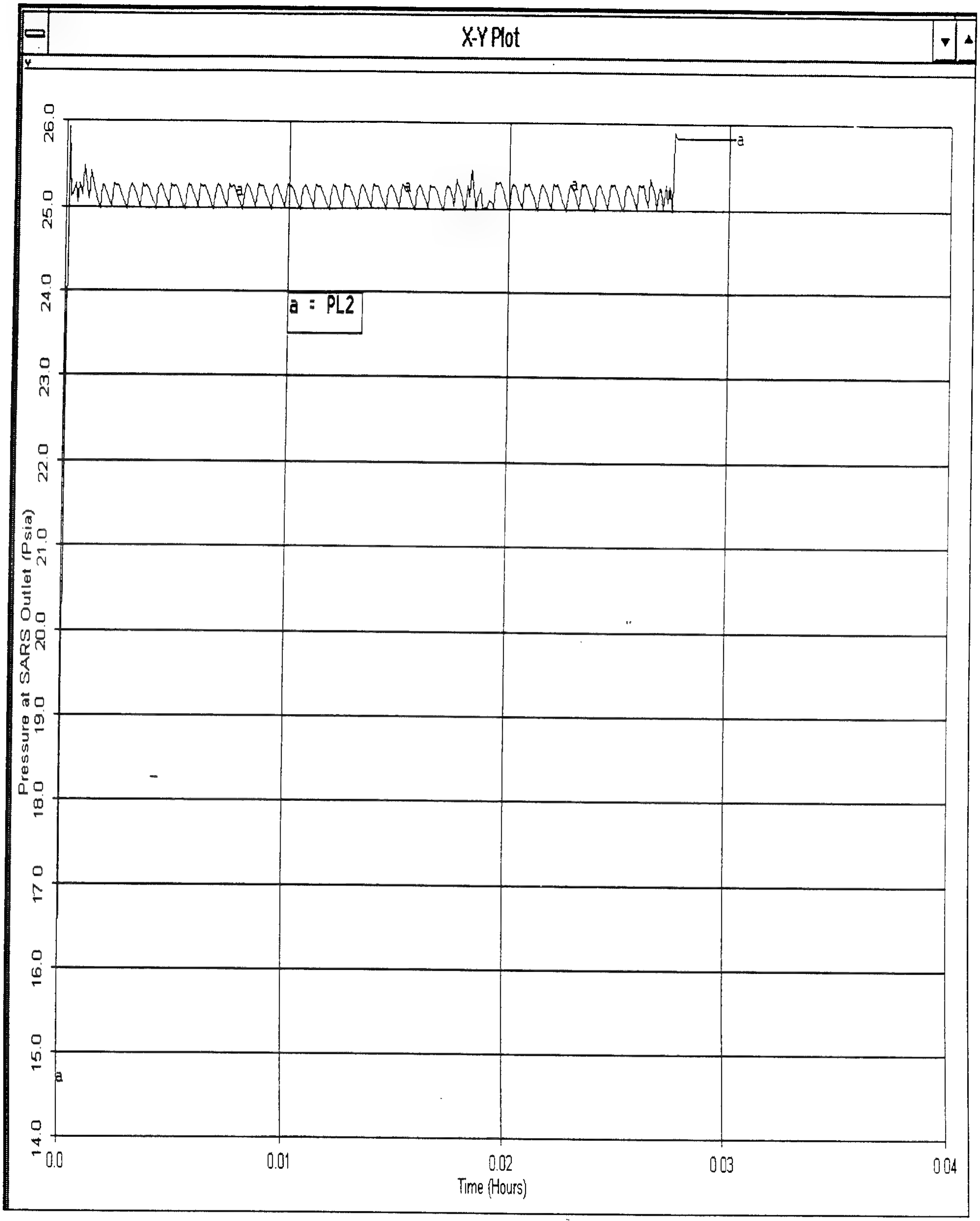
Pressure Spikes Due to Shut-off Valve Closures, Upstream Nodes (a is path to side tank 1, b is path to side tank 2 and c is path to center tank)

Figure 8



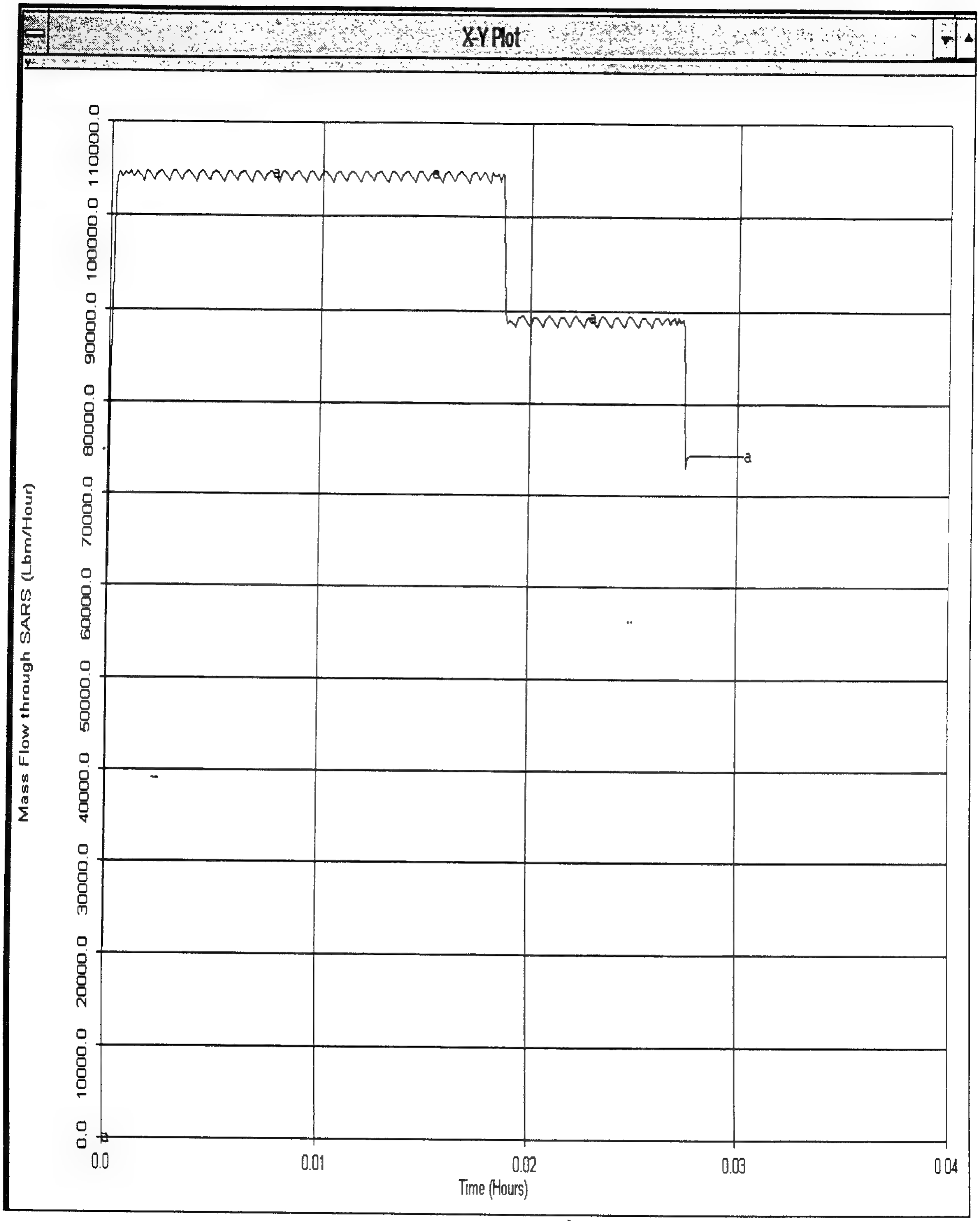
Pressure Through SARS (a is inlet, b is nozzle regulation point and c is the outlet)

Figure 9



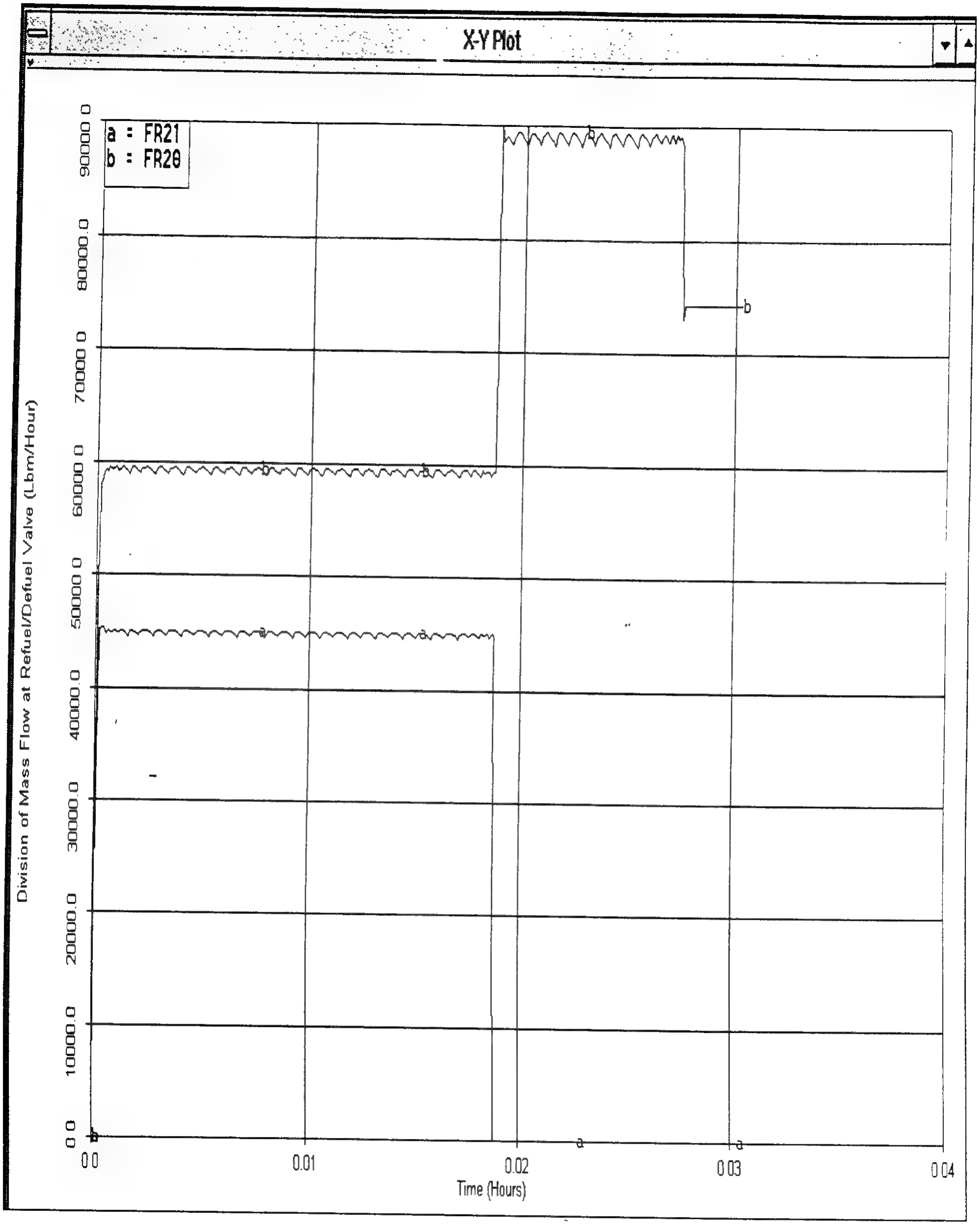
Pressure at SARS outlet

Figure 10



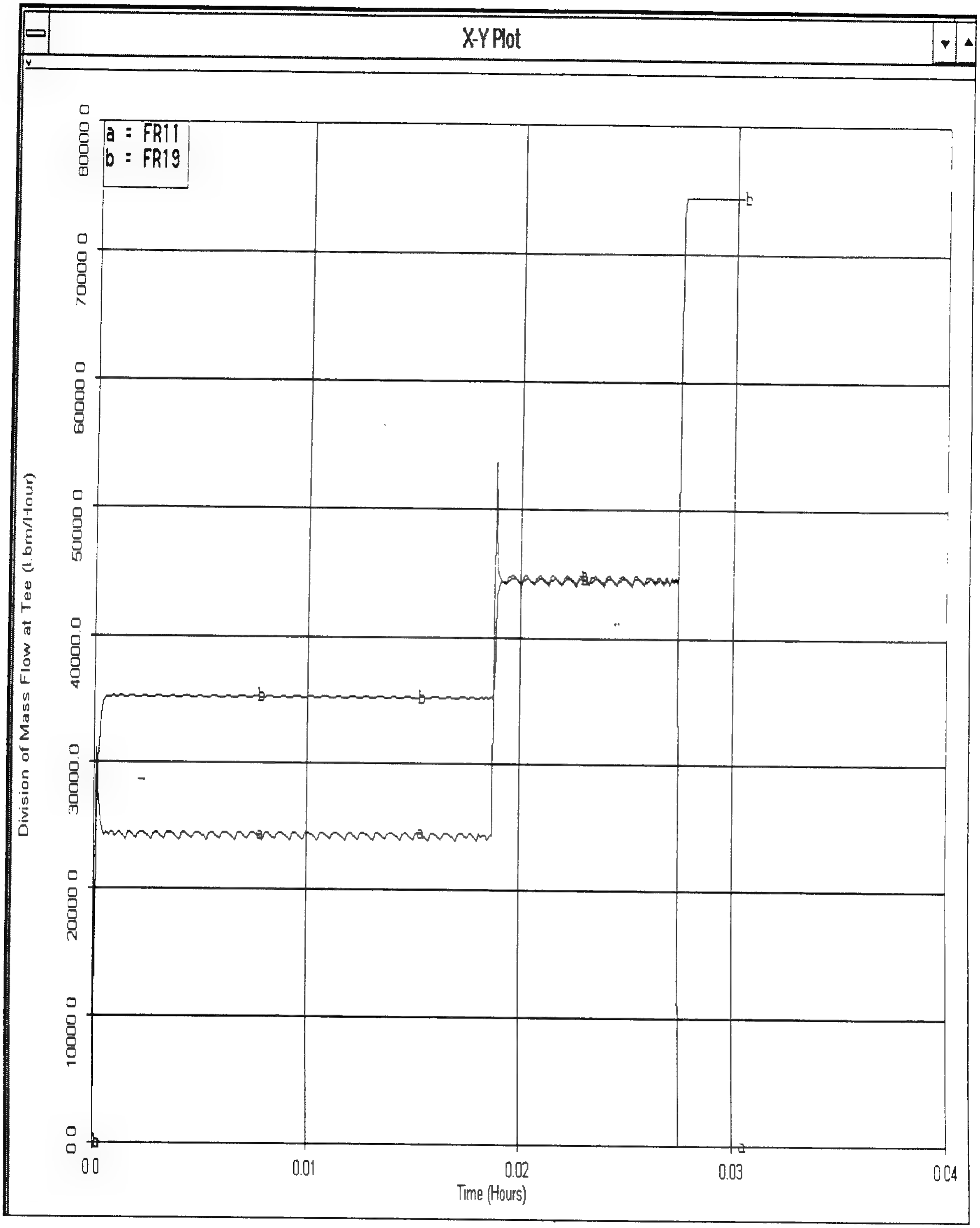
Mass Flow Rate Through Pump (100,100 lbm/hr = 200 gpm for water)

Figure 11



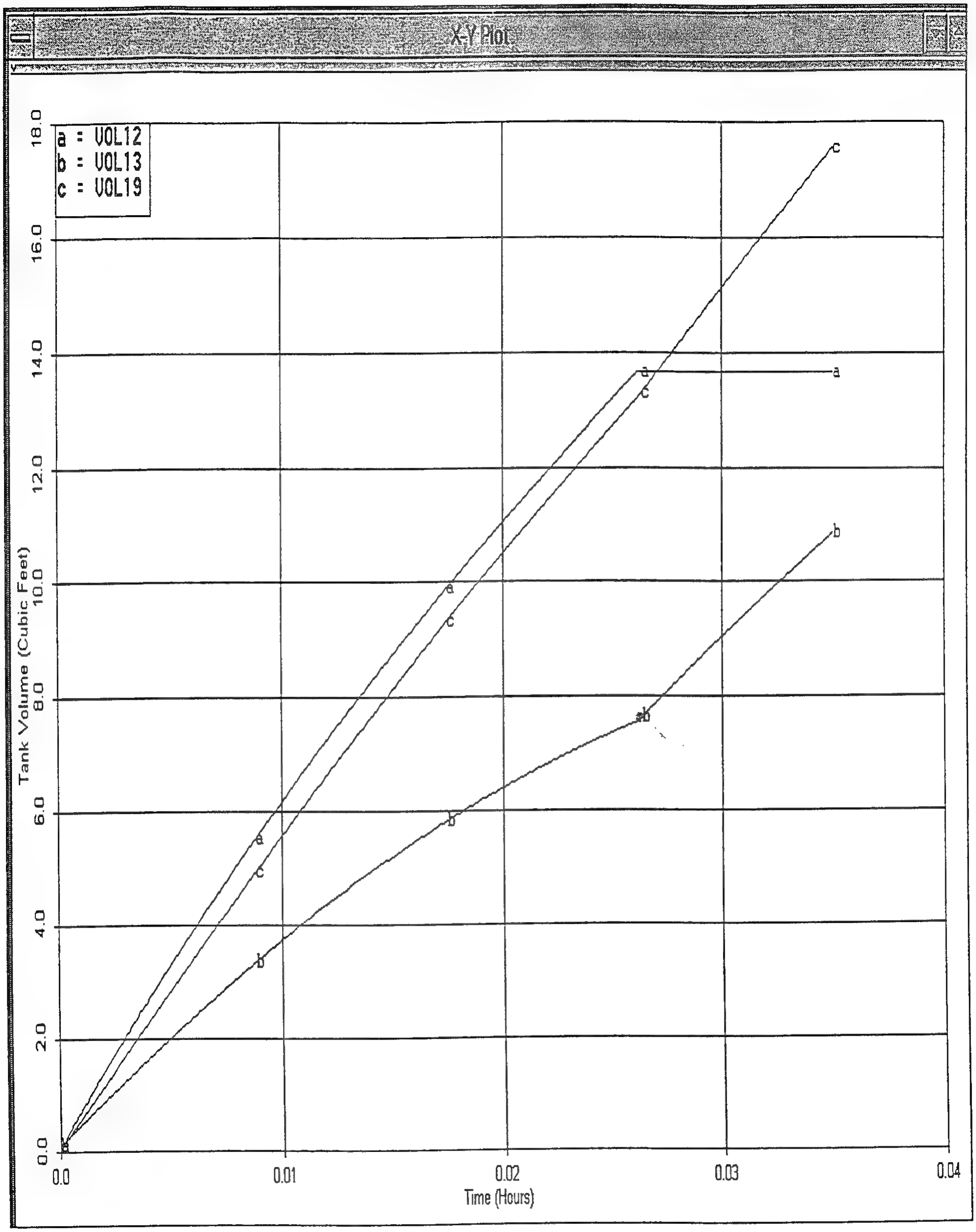
Division of Mass Flow at Refuel/Defuel Valve (a is path to side tank 1 and b is path to side tank 2 and center tank)

Figure 12



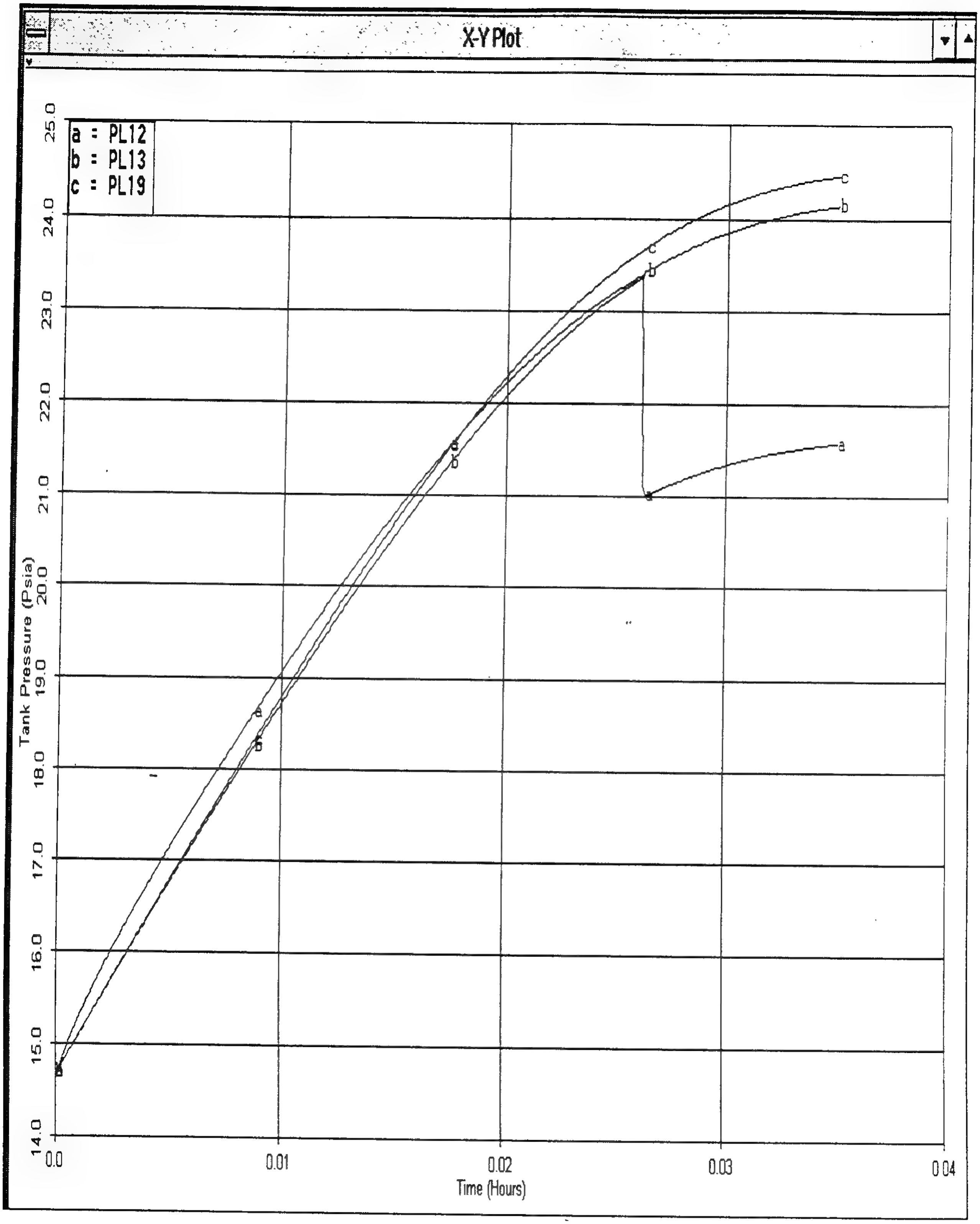
Division of Mass Flow to Side Tank 2 and the Center Tank at a Tee Fitting (a is the path to side tank 2, b is the path to the center tank)

Figure 13



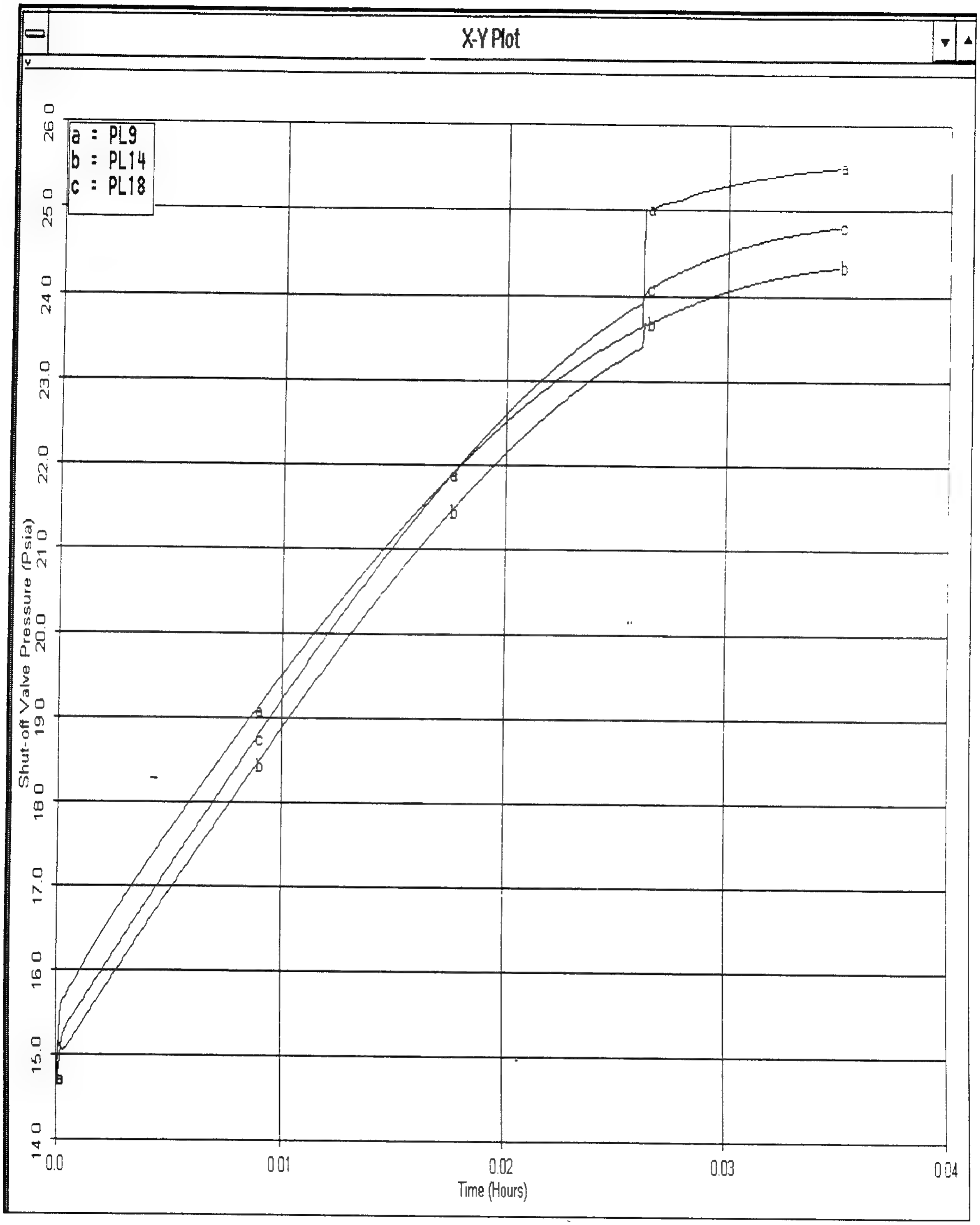
Fuel Tank Volumes as a Function of Time (a and b are side tanks, c is the center tank)

Figure 14



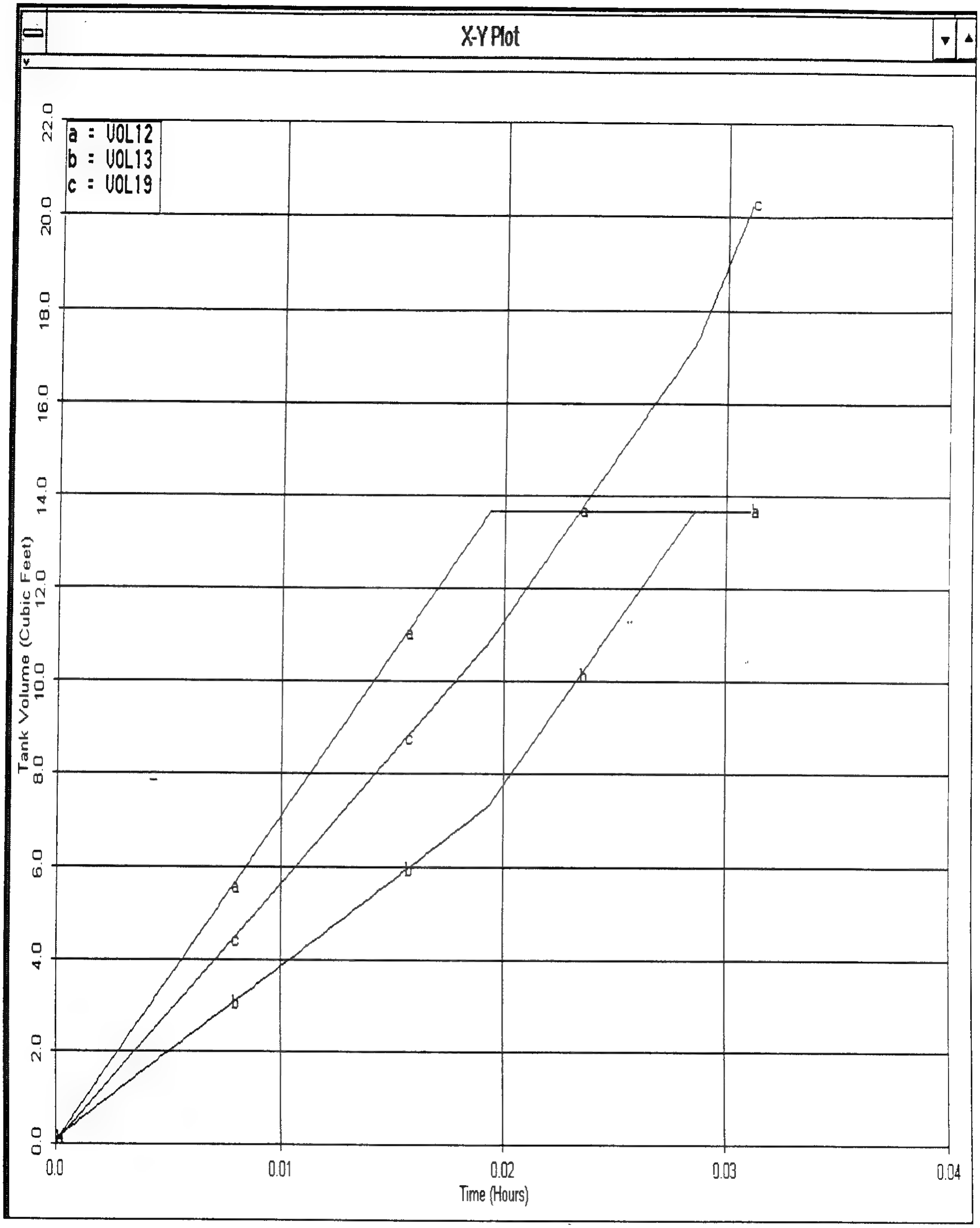
Pressure in Fuel Tanks During Refueling (a and b are side tanks, c is the center tank)

Figure 15



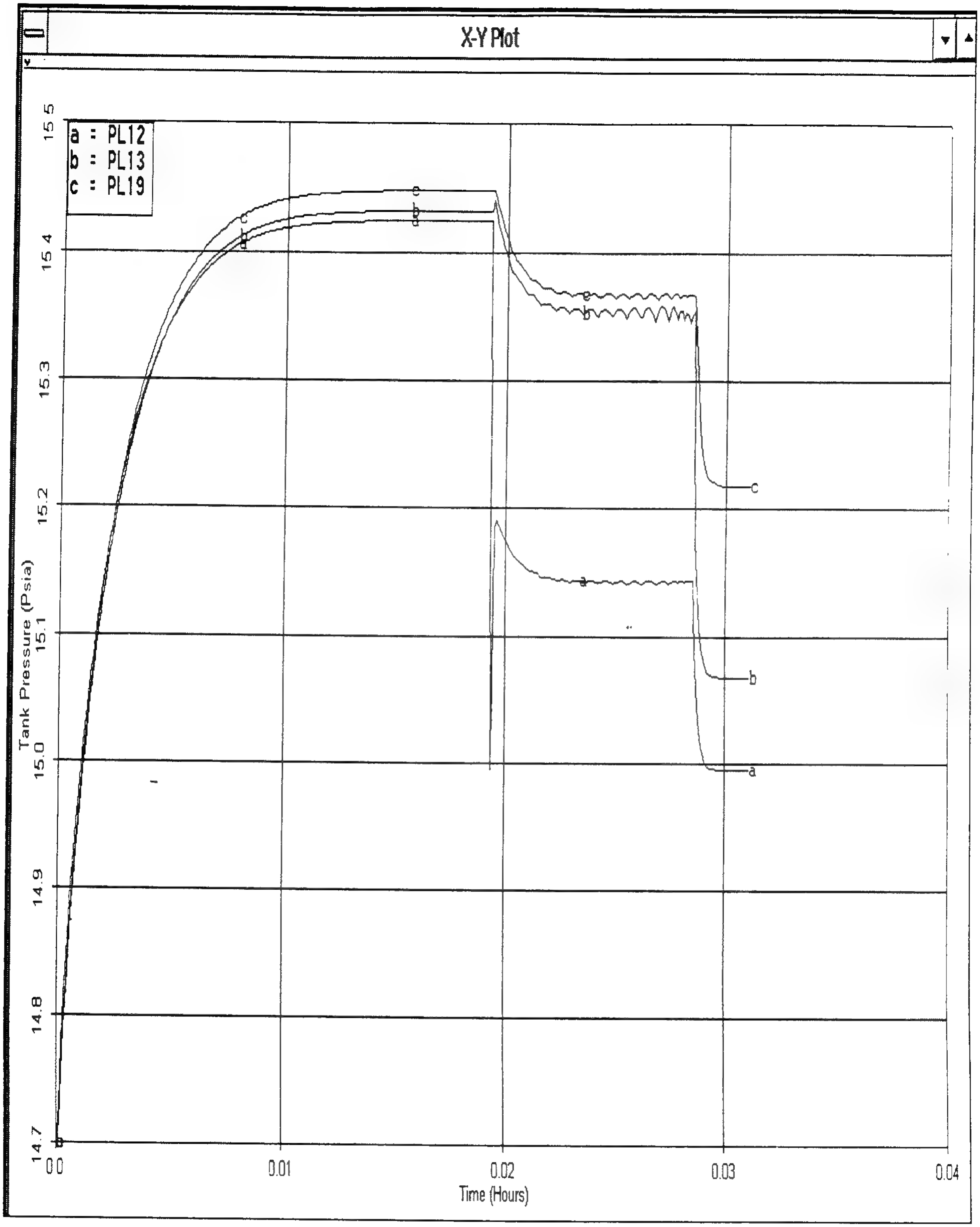
Pressure Spikes Due to Shut-off Valve Closures, Upstream Nodes (a is path to side tank 1, b is path to side tank 2 and c is path to center tank)

Figure 16



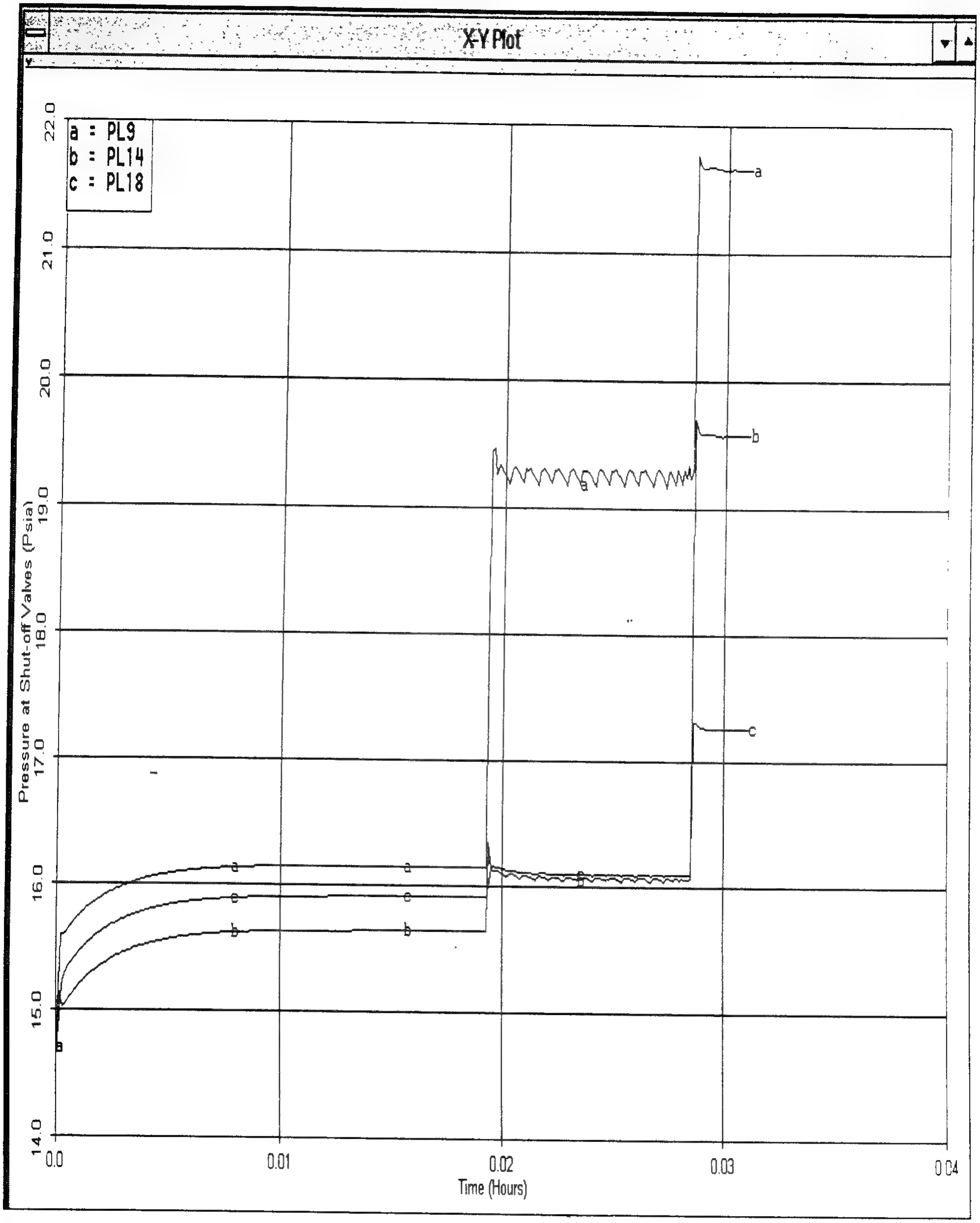
Fuel Tank Volumes as a Function of Time (a and b are side tanks, c is the center tank)

Figure 17



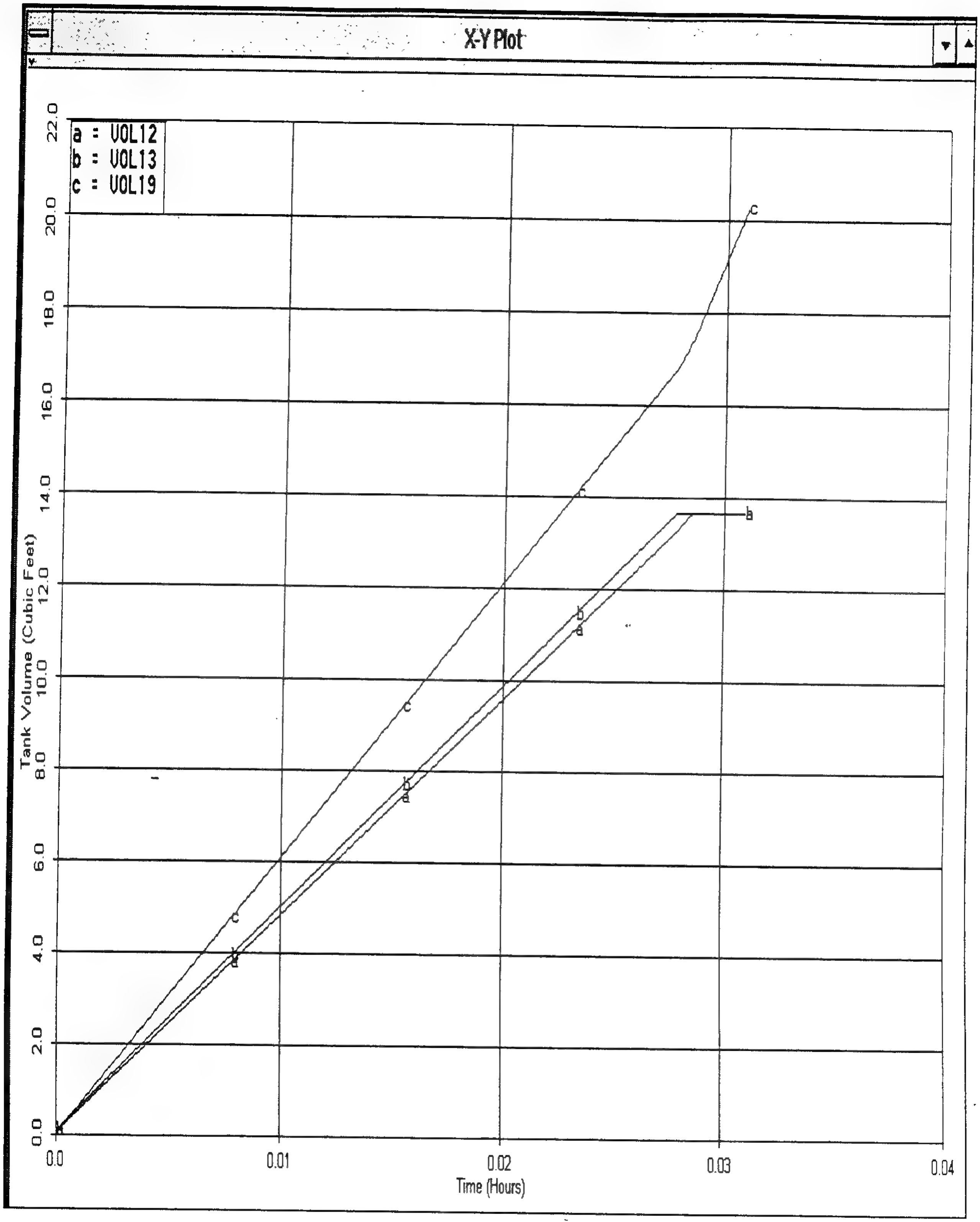
Pressure in Fuel Tanks During Refueling (a and b are side tanks, c is the center tank)

Figure 18



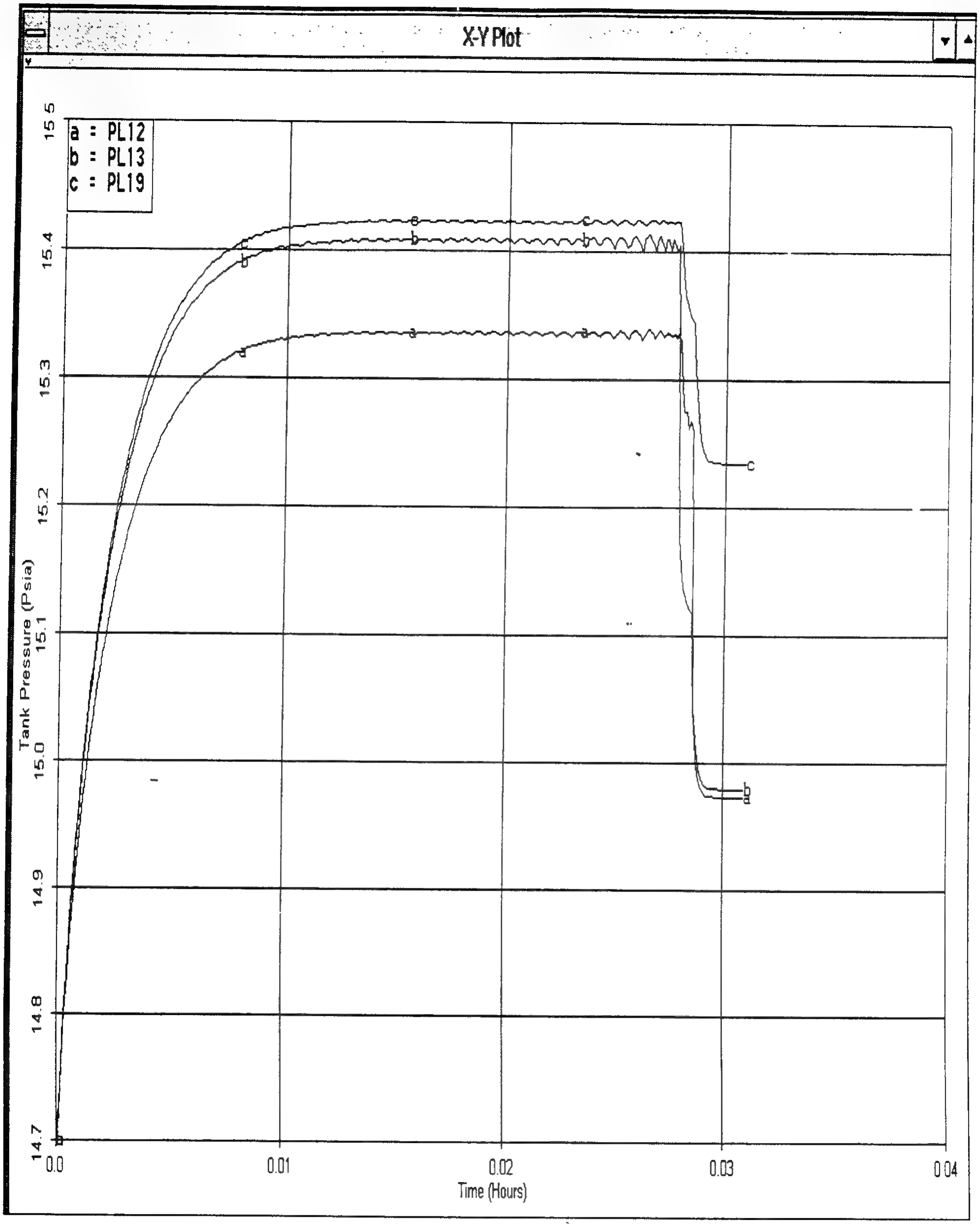
Pressure Spikes Due to Shut-off Valve Closures, Upstream Nodes (a is path to side tank 1, b is path to side tank 2 and c is path to center tank)

Figure 19



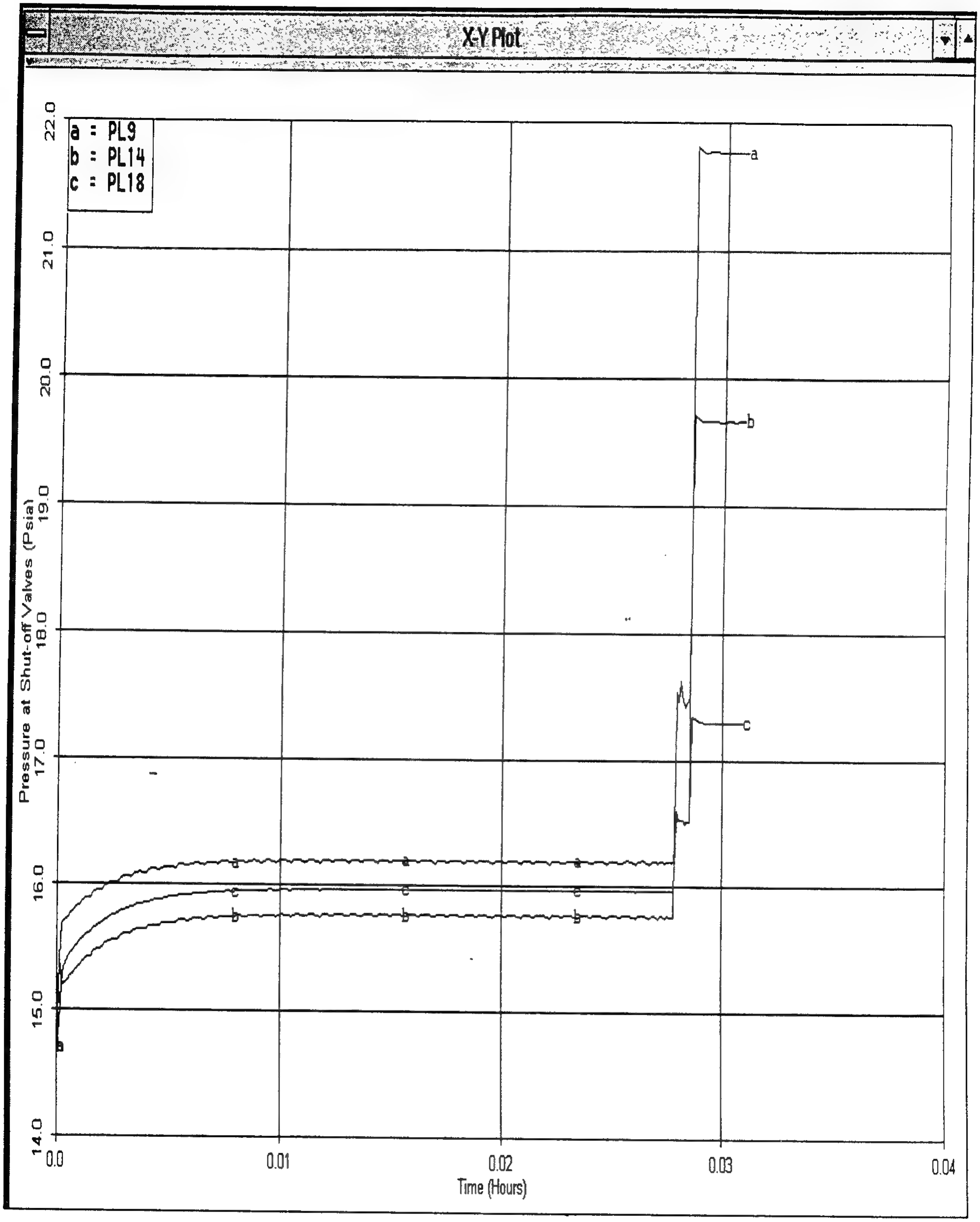
Fuel Tank Volumes as a Function of Time (a and b are side tanks, c is the center tank)

Figure 20



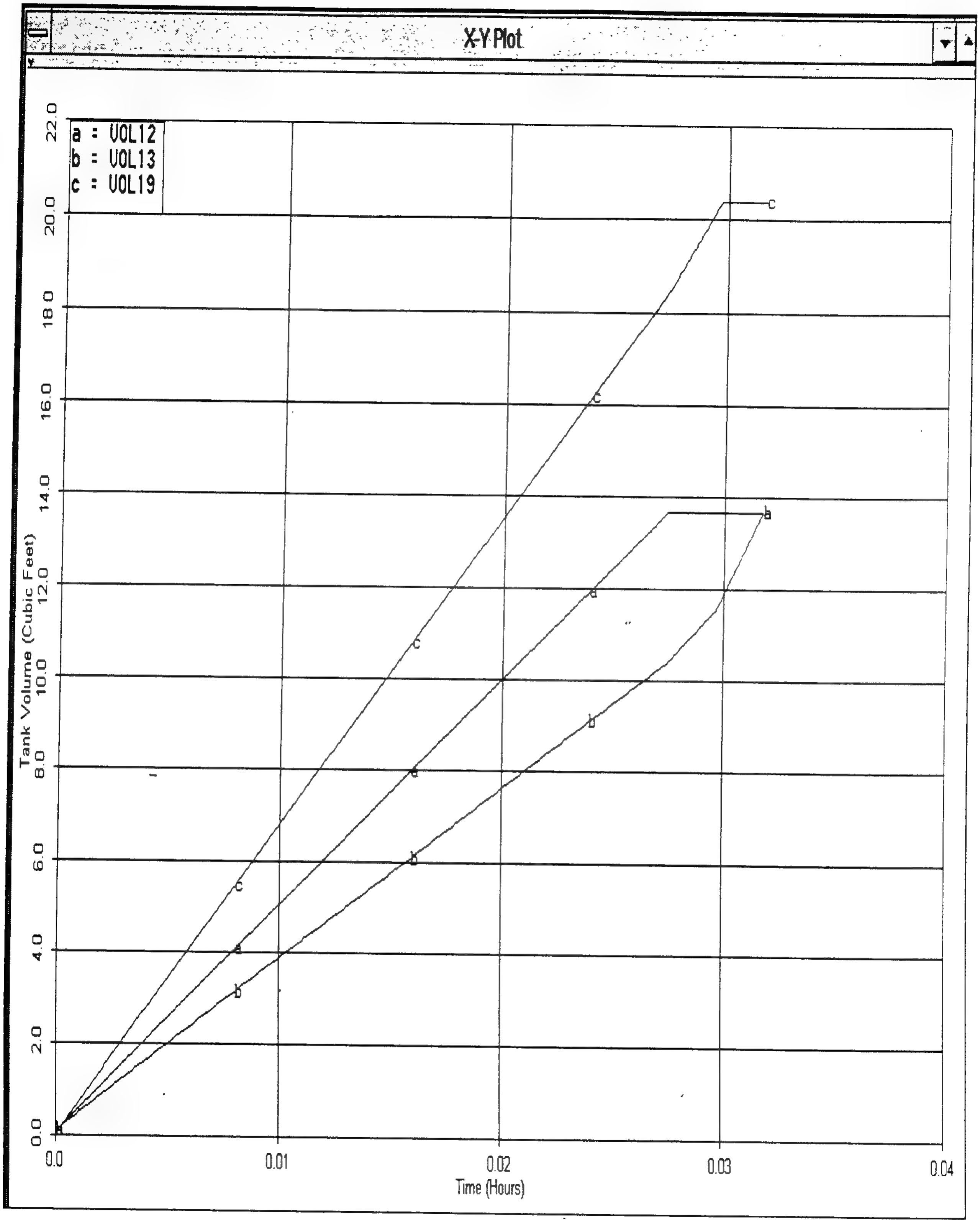
Pressure in Fuel Tanks During Refueling (a and b are side tanks, c is the center tank)

Figure 21



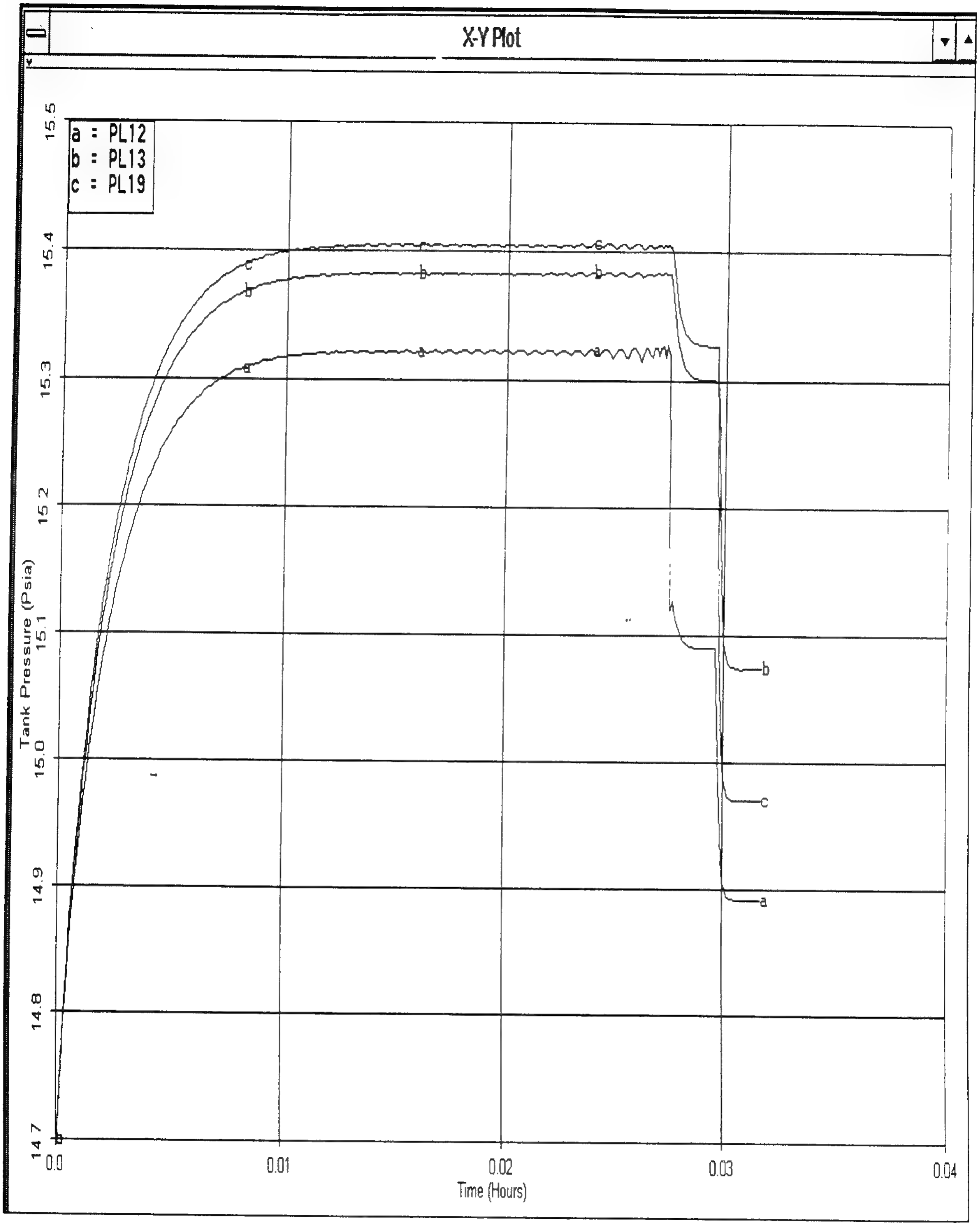
Pressure Spikes Due to Shut-off Valve Closures, Upstream Nodes (a is path to side tank 1, b is path to side tank 2 and c is path to center tank)

Figure 22



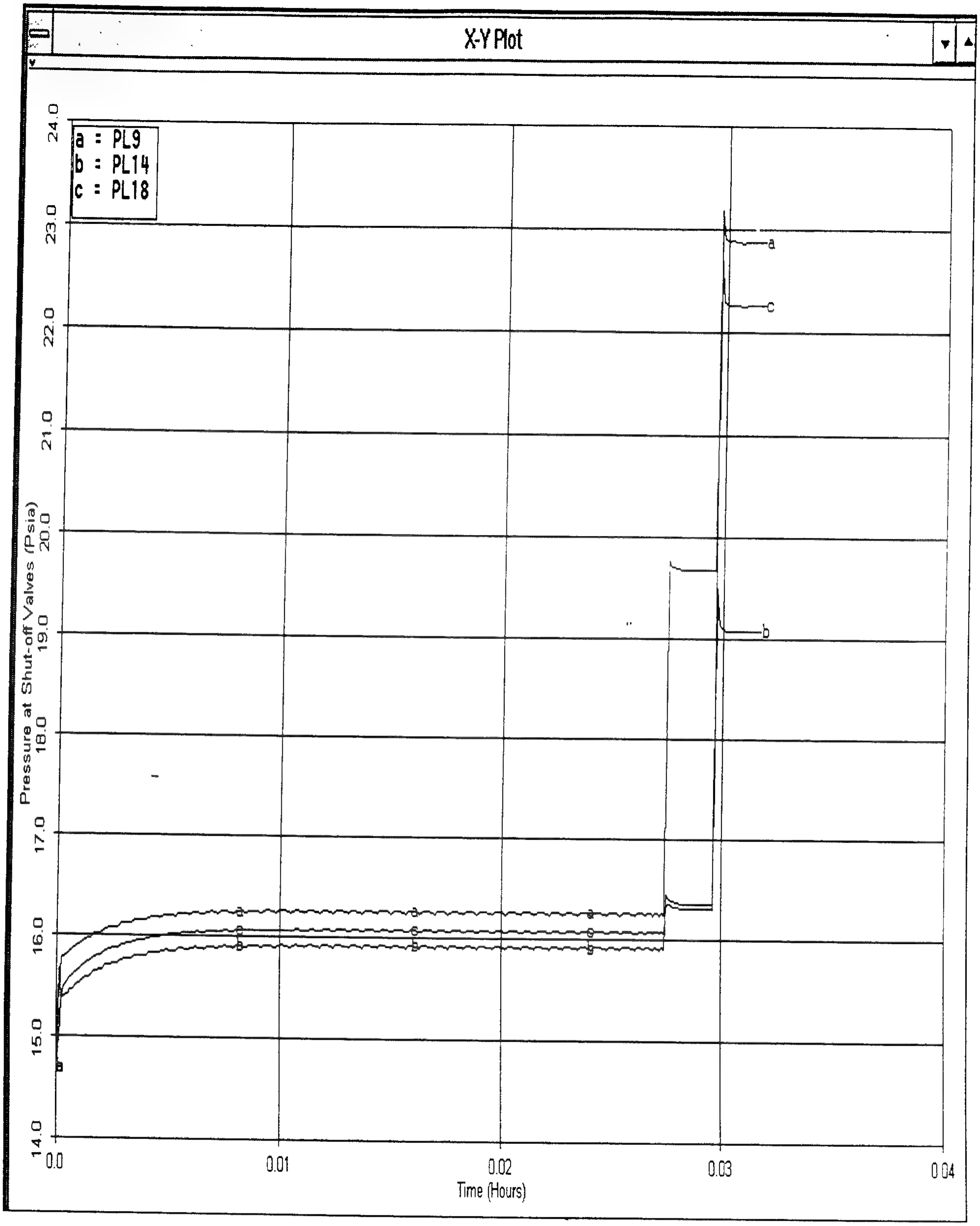
Fuel Tank Volumes as a Function of Time (a and b are side tanks, c is the center tank)

Figure 23



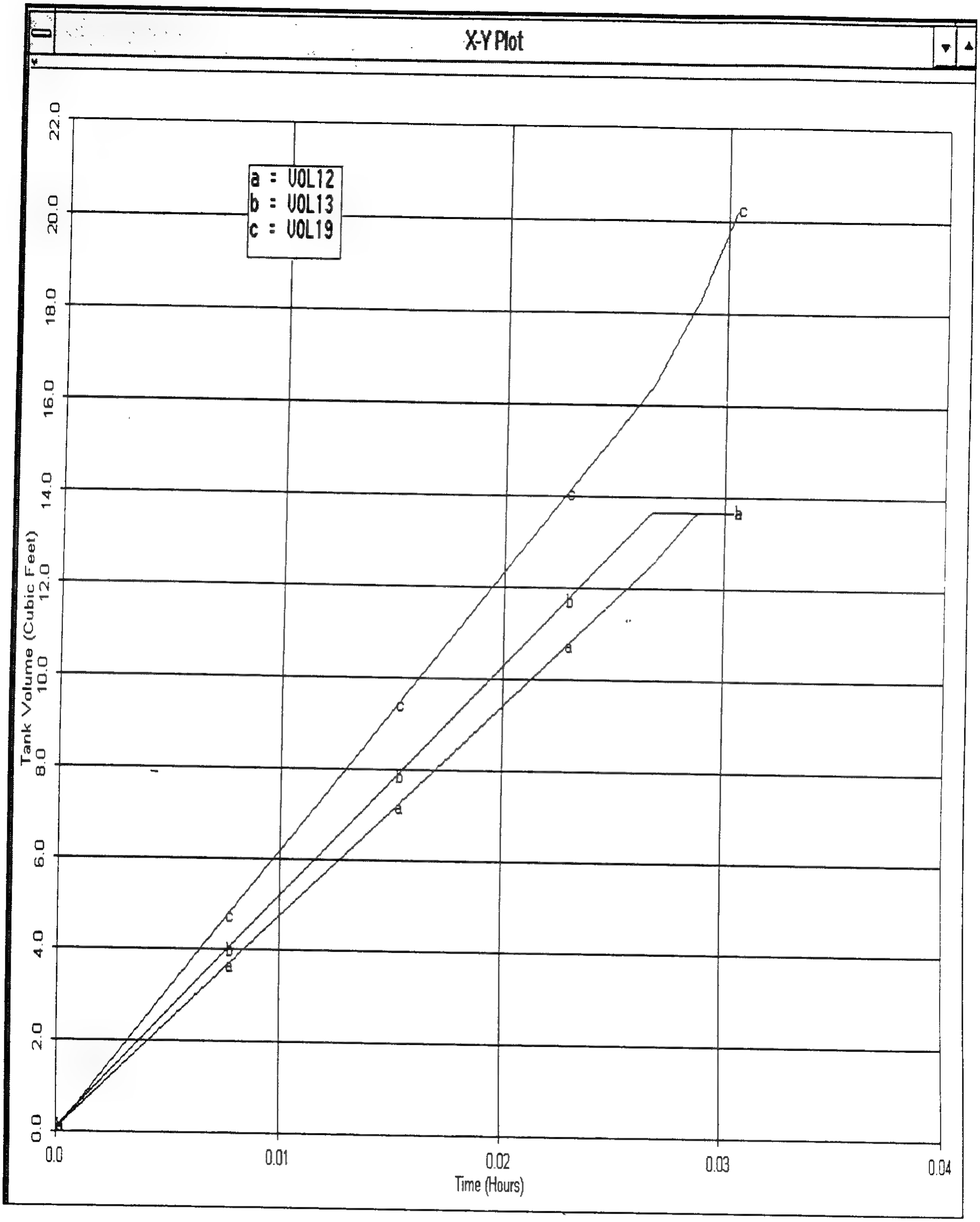
Pressure in Fuel Tanks During Refueling (a and b are side tanks, c is the center tank)

Figure 24



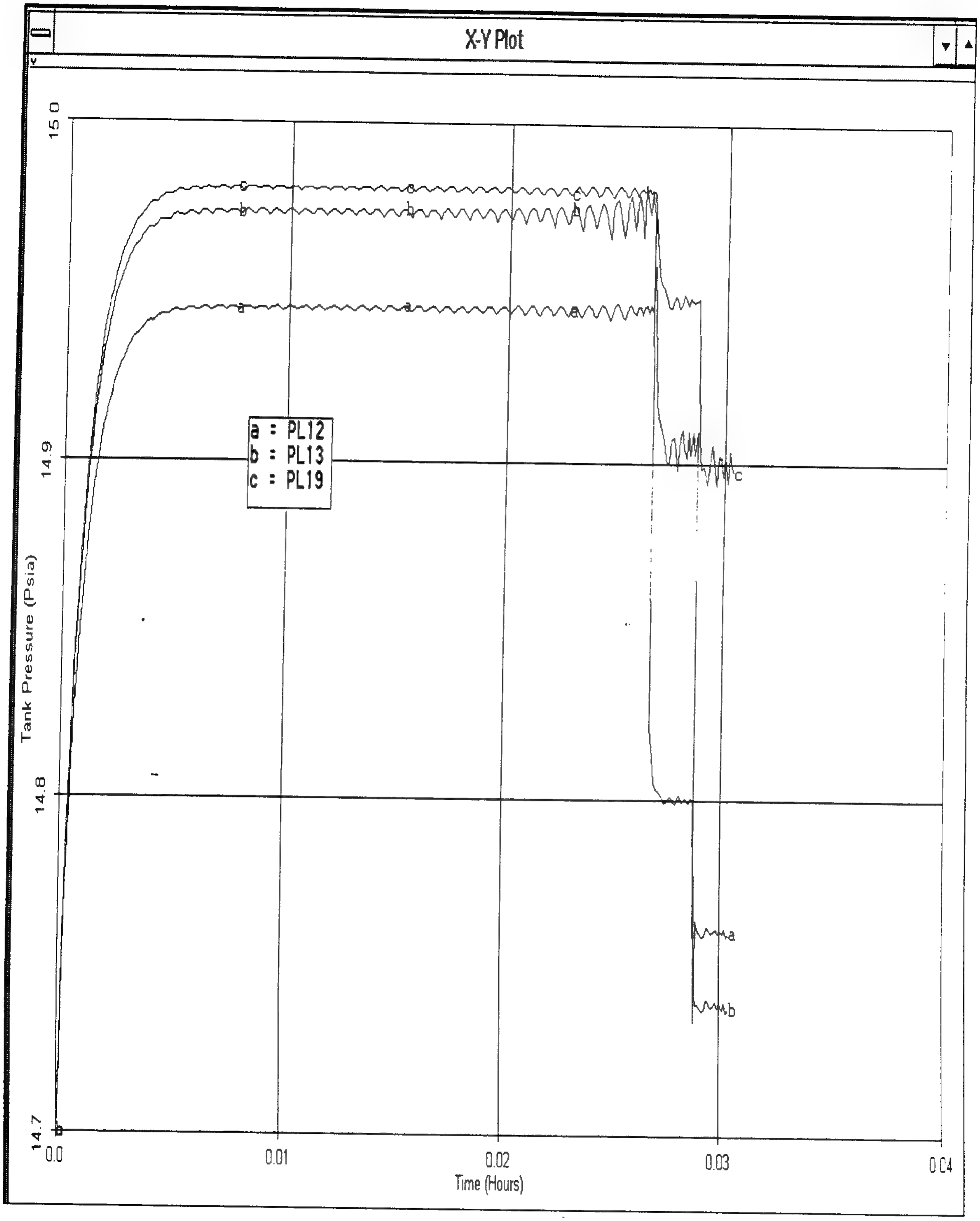
Pressure Spikes Due to Shut-off Valve Closures, Upstream Nodes (a is path to side tank 1, b is path to side tank 2 and c is path to center tank)

Figure 25



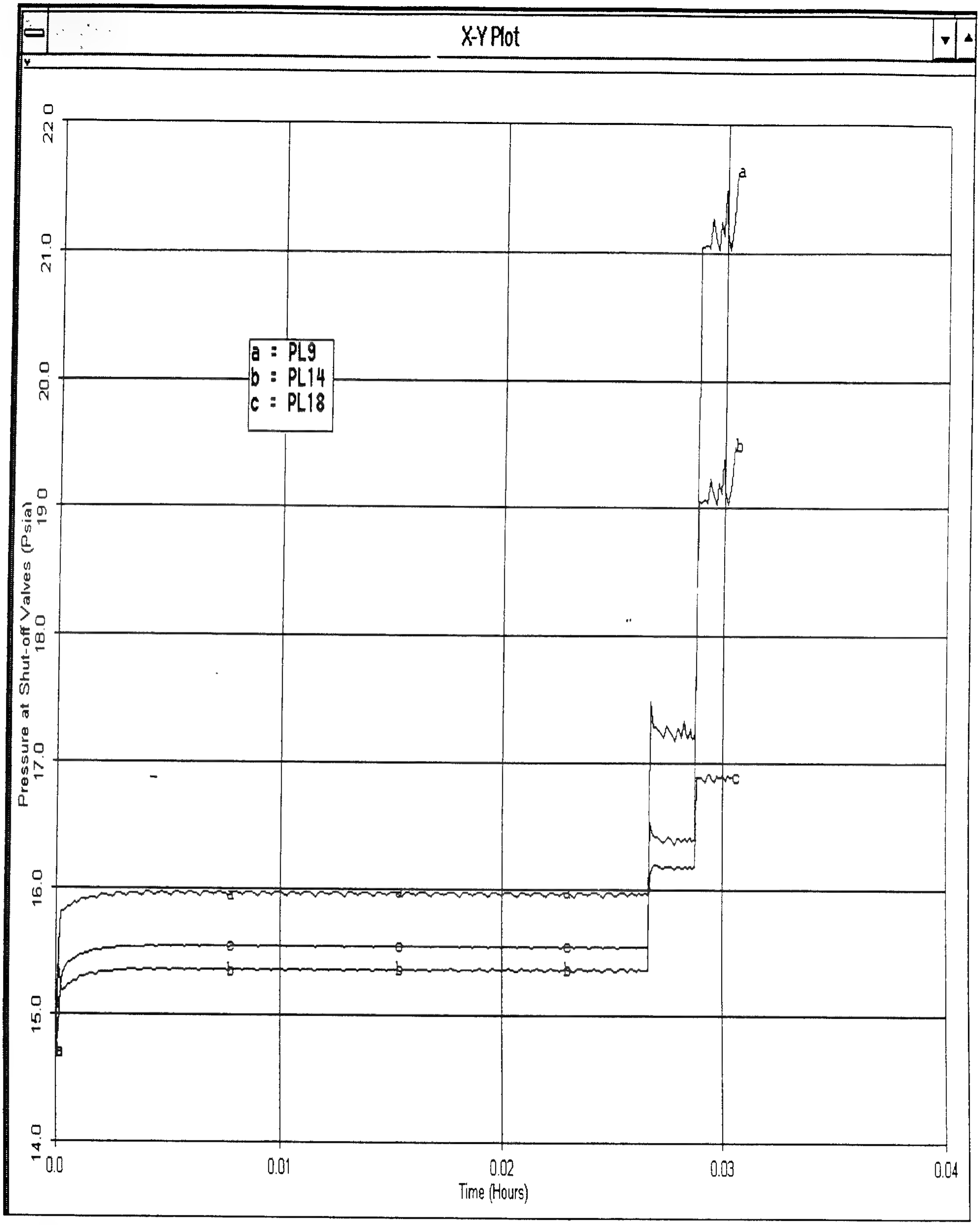
Fuel Tank Volumes as a Function of Time (a and b are side tanks, c is the center tank)

Figure 26



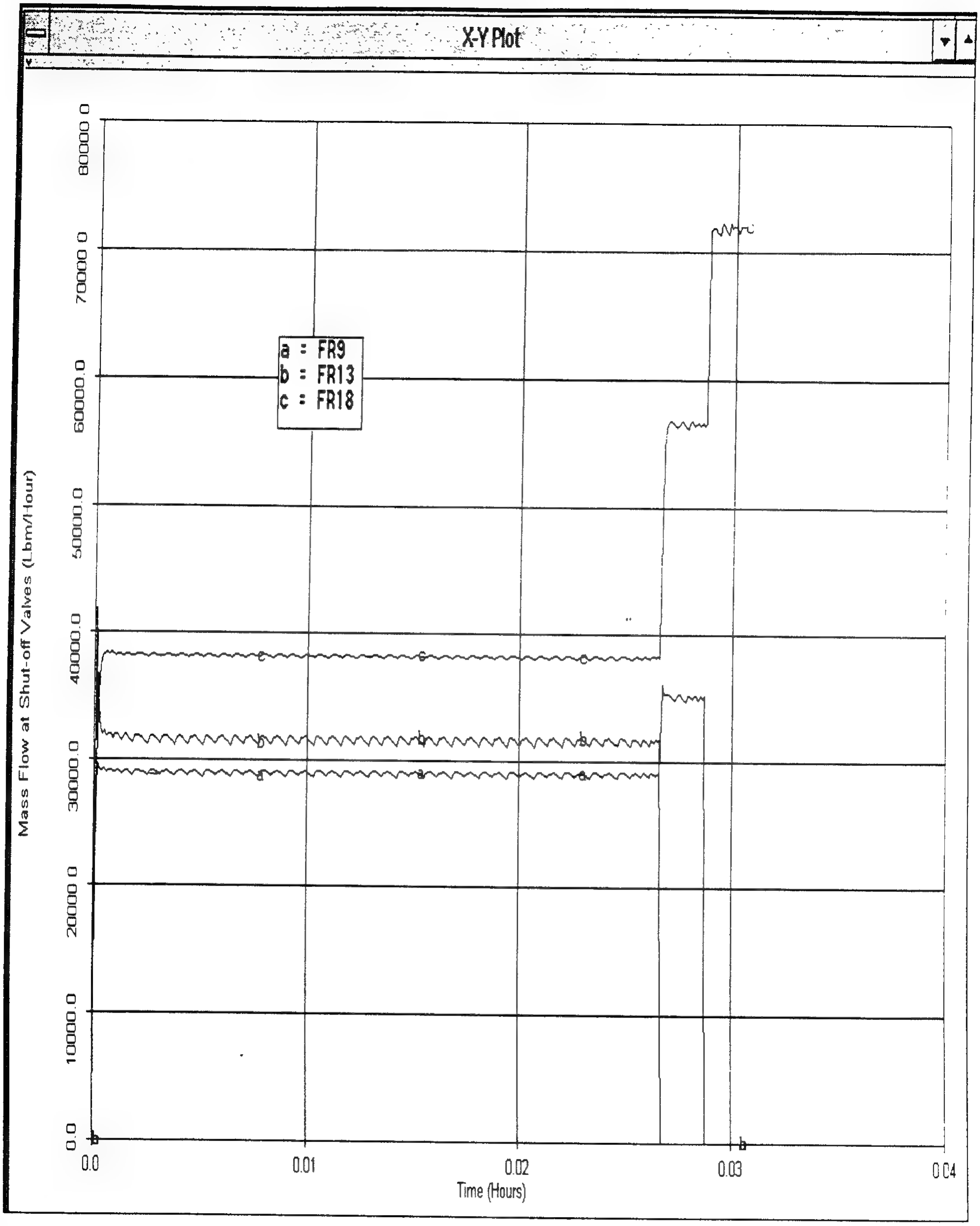
Pressure in Fuel Tanks During Refueling (a and b are side tanks, c is the center tank)

Figure 27



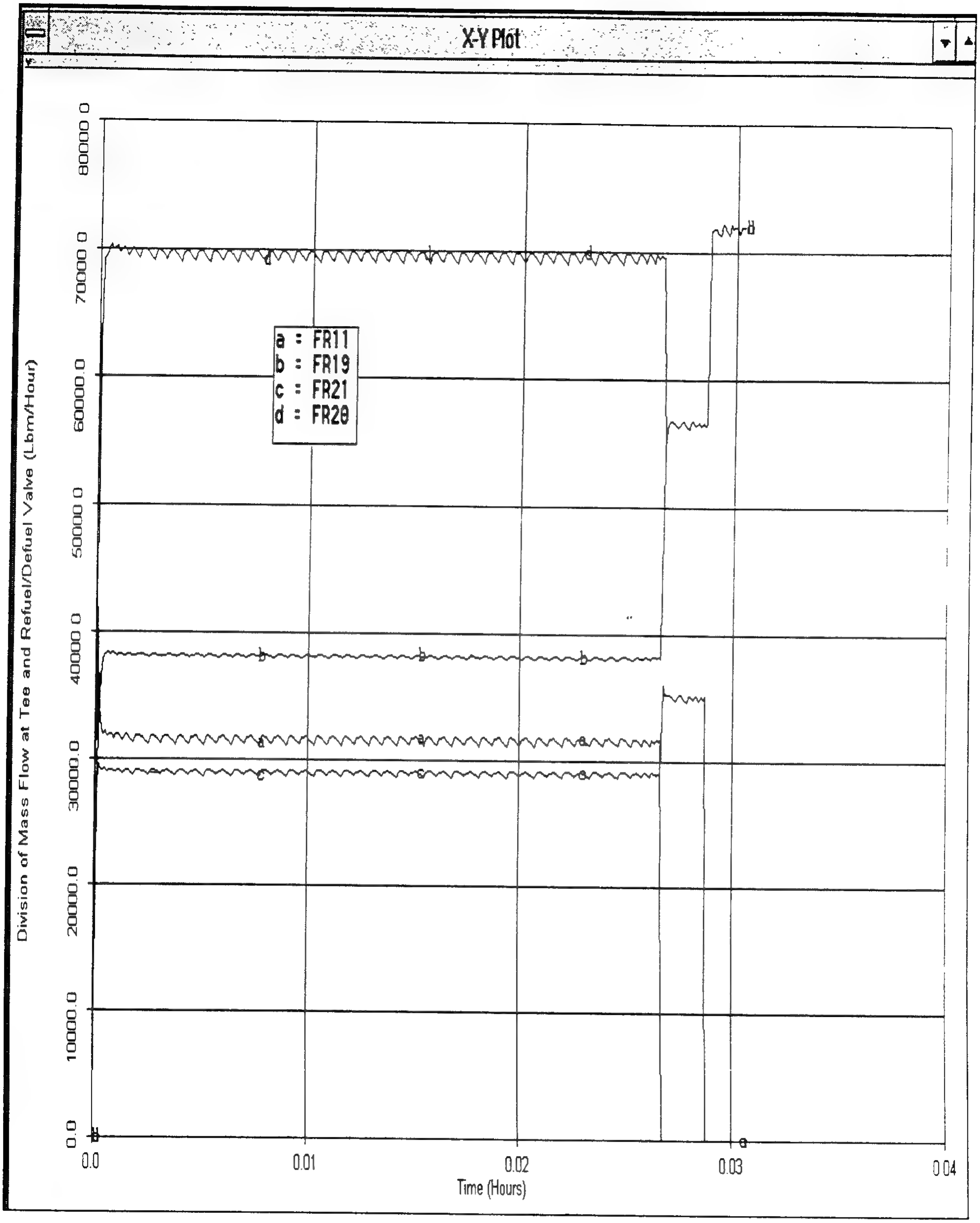
Pressure Spikes Due to Shut-off Valve Closures, Upstream Nodes (a is path to side tank 1, b is path to side tank 2 and c is path to center tank)

Figure 28



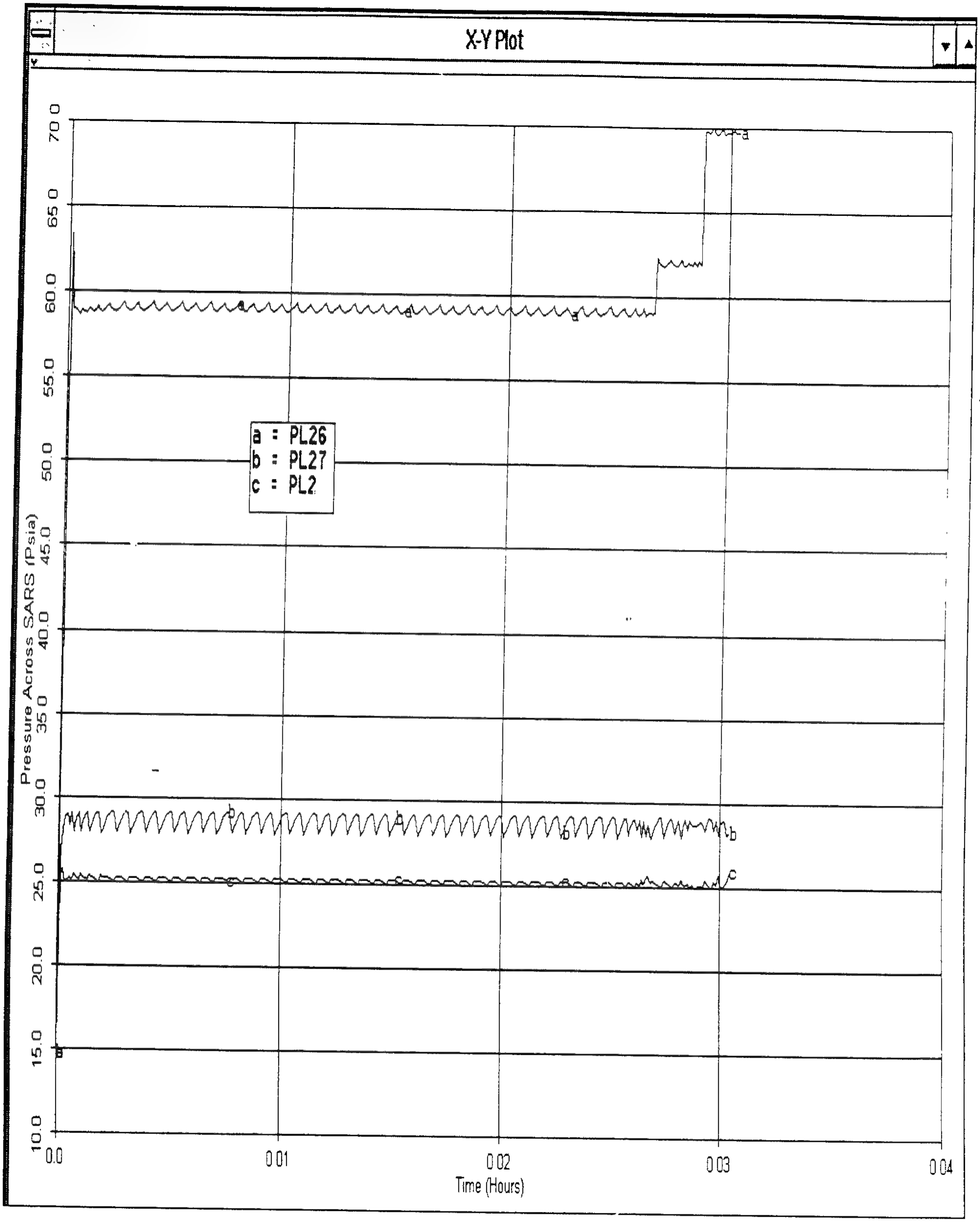
Shut Off Valve Performance (a and b are side tanks, c is the center tank)

Figure 29

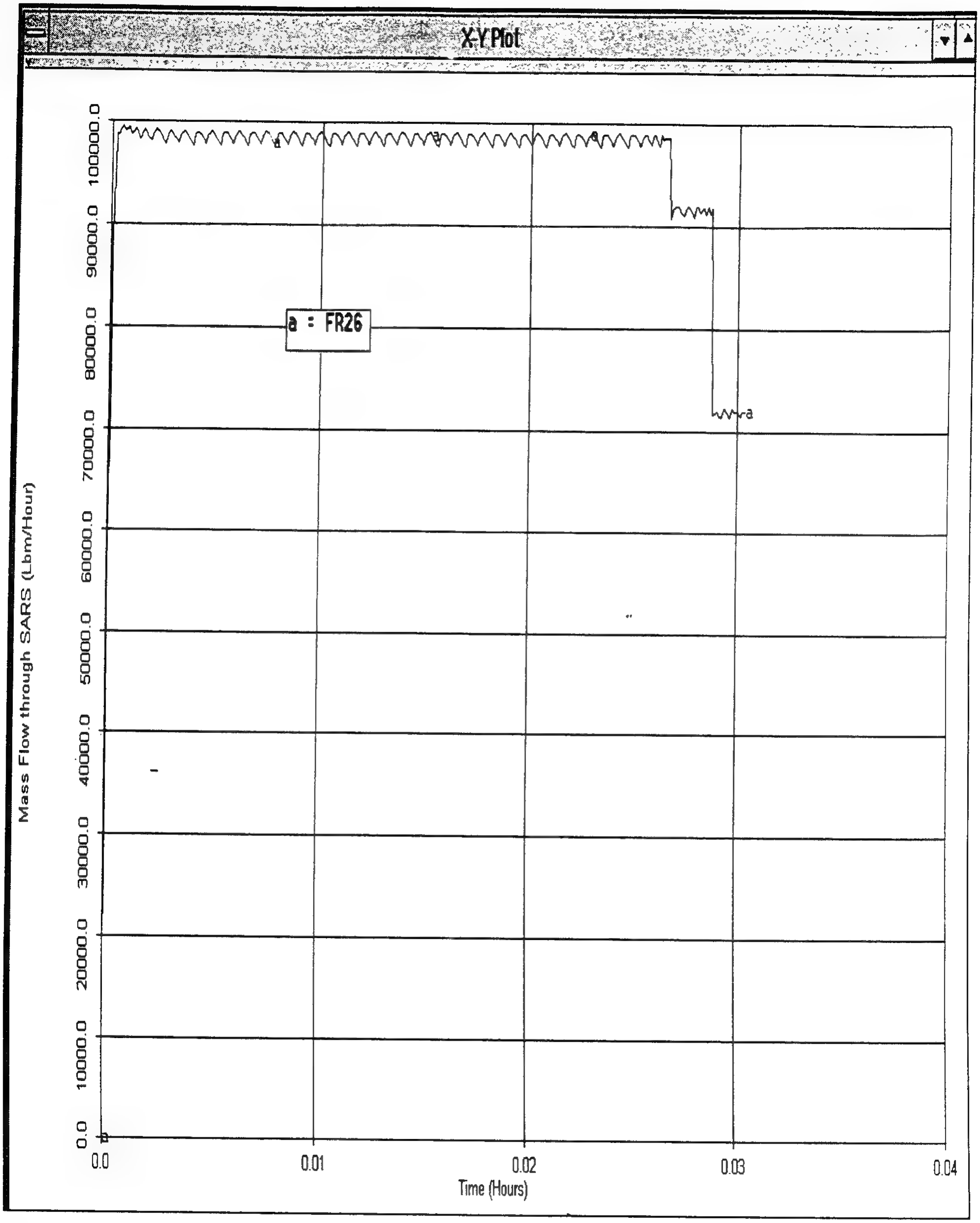


Division of Mass Flow to the Tanks (a is path to side tank 2, b is path to center tank, c is path to side tank 1 and d is path to side tank 2 and center tank)

Figure 30



Pressure Across SARS (a is the inlet pressure, b is the pressure at the regulation point and c is the outlet pressure)
Figure 31



Mass Flow Rate Through Pump (100,100 lbm/hr = 200 gpm water)

Figure 32

```
C    Time of File Output - 28 October 1994 at 1:21:15 pm
HEADER OPTIONS DATA
TITLE     farvfuel
     MODEL      = ROOT
     SAVE = d:\sinda\farvfuel.sav
     OUTPUT     = d:\sinda\farvfuel.out
HEADER OPERATIONS DATA
BUILDF CONFIG, FUEL, VAPOR
     CALL FORWRD
HEADER CONTROL DATA,GLOBAL
     TIMEO      = 0.0
     TIMEND     = 0.035
     NLOOPS     = 0
     ABSZRO     = -459.67
     PATMOS     = 0.0
     SIGMA      = 1.0
     UID  = ENG
     ACCELX     = 0.0
     ACCELY     = 0.0
     ACCELZ     = 4.17312E8
     NLOOPT     = 100
     ARLXCA     = 0.01
     DRLXCA     = 0.01
     EBALSA     = 0.01
     EBALNA     = 0.0
     DTIMEI     = 0.0
     ITEROT     = 0
     ATMPCA     = 1.0E30
     DTMPCA     = 1.0E30
     CSGFAC     = 1.0
     DTIMEL     = 0.0
     DTIMEH     = 1.0E30
     ITHOLD     = 10
     EXTLIM     = 50.0
     ITERXT     = 3
     BACKUP     = 0.0
     OPEITR     = 0
     DTSIZF     = 0.1
     DTMAXF     = 5.0E-5
     DTMINF     = 0.0
     OUTPTF     = 1.0E-4
     OPITRF     = 0
     RSSIZF     = 0.5
     RSMAXF     = 1.0
     RERRF      = 0.01
     REBALF     = 0.01
     ITROTF     = 0
     ITHLDF     = 10
     DTTUBF     = 0.1
     RSTUBF     = 0.5
HEADER USER DATA,GLOBAL
```

```
      GPM=8.021          $CONVERT GPM TO FT^3/HR
      VS=13.769          $ SIDE TANK CAPACITY
      VC=20.453          $ CENTER TANK CAPACITY
      GC=6.009E10        $CONVERSION FACTOR USED IN LOSS CONNECTOR
 EXPRESSION
      AA=0.0             $PLACEHOLDER FOR VALUE OF FLOWRATE AT 25PSI
 IN SARS RECEPTACLE
      II=0               $DUMMY FLAG FOR SARS RECEPTACLE KICK-IN
 HEADER FPROP DATA,8001,ENG,-459.67
      RGAS=51.5
      CP=1.
      K=1.
      V=.044
 HEADER ARRAY DATA,FUEL

 521=0.0,179.,320.8,166.4,641.7,152.9,962.5,138.1,1283.3,121.5,160
 4.2,102.2,1925.0,78.3,2245.8,42.8
      $ PUMP 1 HEAD CURVE

 522=0.0,165.1,320.8,151.5,641.7,136.5,962.5,119.7,1283.3,100.1,16
 04.2,75.5,1925.0,37.3
      $ PUMP 2 HEAD CURVE
 HEADER FLOGIC0,FUEL
 $this code links the fuel tanks to the vapor cycle
      COMP(12)=vapor.vol(10)/(vapor.pl(10)*vol(12))
      vdot(12)=vapor.fr(18)/vapor.dl(10)
      COMP(13)=vapor.vol(9)/(vapor.pl(9)*vol(13))
      vdot(13)=vapor.fr(7)/vapor.dl(9)
      COMP(19)=vapor.vol(11)/(vapor.pl(11)*vol(19))
      vdot(19)=vapor.fr(10)/vapor.dl(11)
 $this code describes the SARS nozzle
      if ((pl(26).gt.29.0).and.(fr(25).gt.0.0))
      !fk(25)=(pl(26)-28.7)*(2.0*gc*dl(26))/(fr(25)/af(25))**2
 $14psig regulated SARS
 $    fk(25)=(pl(26)-32.7)*(2.0*gc*dl(26))/(fr(25)/af(25))**2
 $18psig regulated SARS
 $    fk(25)=(pl(26)-36.7)*(2.0*gc*dl(26))/(fr(25)/af(25))**2
 $22psig regulated SARS
 $this code describes shut-off valve behavior
      if (vol(12).ge.(vs-.1)) fk(9)=-1.0
      if (vol(13).ge.(vs-.1)) fk(13)=-1.0
      if (vol(19).ge.(vc-.1)) fk(18)=-1.0
 $this code describes SARS receptacle performance
      if (pl(2).gt.25.0) then
       ii=ii+1
       if (ii.eq.1) aa=fr(26)
       fk(26)=2.0*gc*dl(27)*(pl(27)-pl(2))/
      !((aa/5.0)*(30.0-pl(2))/af(26))**2
      else
       ii=0
       fk(26)=.1
      endif

 HEADER OUTPUT CALLS,FUEL
```

```
$     CALL PTHTAB('FUEL')
$     CALL LMXTAB('FUEL')
$     CALL LMPTAB('FUEL')
      CALL SAVE('ALL',0)
HEADER FLOW DATA,FUEL, FID = 718
LU PLEN,1, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.7817
LU TANK,2, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.7817
     , VOL=0.0603, QDOT=0.0, VDOT=0.0, COMP=0.0
LU TANK,3, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.7817
     , VOL=0.0603, QDOT=0.0, VDOT=0.0, COMP=0.0
LU JUNC,4, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.7817,
QDOT=0.0
LU JUNC,5, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,6, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,8, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU TANK,9, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0
     , VOL=0.0547, QDOT=0.0, VDOT=0.0, COMP=0.0
LU TANK,10, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0
     , VOL=0.0299, QDOT=0.0, VDOT=0.0, COMP=0.0
LU TANK,11, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0
     , VOL=0.0671, QDOT=0.0, VDOT=0.0, COMP=0.0
LU TANK,12, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0
     , VOL=0.1, QDOT=0.0, VDOT=0.0, COMP=0.0
LU TANK,13, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0
     , VOL=0.1, QDOT=0.0, VDOT=0.0, COMP=0.0
LU JUNC,14, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU TANK,15, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0
     , VOL=0.0671, QDOT=0.0, VDOT=0.0, COMP=0.0
LU TANK,16, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0
     , VOL=0.0246, QDOT=0.0, VDOT=0.0, COMP=0.0
LU TANK,17, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=-2.255
     , VOL=0.0246, QDOT=0.0, VDOT=0.0, COMP=0.0
LU JUNC,18, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=-2.255,
QDOT=0.0
LU TANK,19, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=-2.255
     , VOL=0.1, QDOT=0.0, VDOT=0.0, COMP=0.0
LU JUNC,20, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU TANK,21, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0
     , VOL=0.0299, QDOT=0.0, VDOT=0.0, COMP=0.0
LU TANK,22, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0
     , VOL=0.0547, QDOT=0.0, VDOT=0.0, COMP=0.0
LU JUNC,23, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,24, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,25, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=-2.255,
QDOT=0.0
LU JUNC,26, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.7817,
QDOT=0.0
```

```
LU JUNC,27, TL=70.0, XL=0.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.7817,
QDOT=0.0
PA CONN,1,1,26, FR=100100.0, STAT=NORM, DUPI=1.0, DUPJ=1.0,
EI=0.0, EJ=0.0, DK=0.0, HK=0.0
     DEV=PUMP , HG=521

PA TUBE,2,2,3, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0
     , TLEN=5.529, DH=0.166667, AF=0.021817, WRF=3.0e-5, HC=0.0,
FC=0.0, FPOW=1.0
     , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,3,3,4, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=LOSS , FK=1.14, AF=0.021817, TPF=1.0

PA CONN,4,4,5, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=STUBE , TLEN=0.7817, DH=0.16667, AF=0.021817, WRF=3.0e-5
          , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
FD=0.0, FG=0.0
PA CONN,5,5,6, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=LOSS , FK=1.14, AF=0.021817, TPF=1.0

PA CONN,6,6,8, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=STUBE , TLEN=1.4483, DH=0.166667, AF=0.021817,
WRF=3.0e-5
          , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
FD=0.0, FG=0.0
PA TUBE,8,22,9, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0
     , TLEN=5.01, DH=0.166667, AF=0.021817, WRF=3.0e-5, HC=0.0,
FC=0.0, FPOW=1.0
     , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,9,9,23, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=CTLVLV , FK=0.36, AF=0.021817, TPF=1.0

PA TUBE,10,21,10, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0
     , TLEN=2.74, DH=0.166667, AF=0.021817, WRF=3.0e-5, HC=0.0,
FC=0.0, FPOW=1.0
     , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,11,10,20, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=LOSS , FK=0.38, AF=0.021817, TPF=1.0

PA CONN,12,20,14, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=STUBE , TLEN=1.63, DH=0.166667, AF=0.021817, WRF=3.0e-5
          , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
FD=0.0, FG=0.0
PA CONN,13,14,24, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=CTLVLV , FK=0.36, AF=0.021817, TPF=1.0
```

```
PA TUBE,14,11,15, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0
      , TLEN=6.15083, DH=0.166667, AF=0.021817, WRF=3.0e-5,
HC=0.0, FC=0.0, FPOW=1.0
      , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,15,15,16, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=0.15, AF=0.021817, TPF=1.0

PA TUBE,16,16,17, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0
      , TLEN=2.255, DH=0.166667, AF=0.021817, WRF=3.0e-5, HC=0.0,
FC=0.0, FPOW=1.0
      , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,17,17,18, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=0.15, AF=0.021817, TPF=1.0

PA CONN,18,18,25, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=CTLVLV , FK=0.36, AF=0.021817, TPF=1.0

PA CONN,19,10,11, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=1.14, AF=0.021817, TPF=1.0

PA CONN,20,8,21, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=1.14, AF=0.021817, TPF=1.0

PA CONN,21,8,22, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=1.14, AF=0.021817, TPF=1.0

PA CONN,22,23,12, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=1.0, AF=0.021817, TPF=1.0

PA CONN,23,24,13, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=1.0, AF=0.021817, TPF=1.0

PA CONN,24,25,19, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=1.0, AF=0.021817, TPF=1.0

PA CONN,25,26,27, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=0.1, AF=0.21817, TPF=1.0

PA CONN,26,27,2, FR=0.0, STAT=NORM, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=0.1, AF=0.021817, TPF=1.0

HEADER FLOGIC0,VAPOR
      vdot(10)=-1.0*fuel.fr(9)/fuel.dl(12)
```

```
      vdot(9)=-1.0*fuel.fr(13)/fuel.dl(13)
      vdot(11)=-1.0*fuel.fr(18)/fuel.dl(19)
HEADER OUTPUT CALLS,VAPOR
$     call pthtab('vapor')
$     call lmptab('vapor')
$     call lmxtab('vapor')
      call save('all',0)
HEADER FLOW DATA,VAPOR, FID = 8001
LU JUNC,8, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=2.64,
QDOT=0.0
LU TANK,9, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0
     , VOL=13.77, QDOT=0.0, VDOT=0.0, COMP=0.0
LU TANK,10, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0
     , VOL=13.77, QDOT=0.0, VDOT=0.0, COMP=0.0
LU TANK,11, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0
     , VOL=20.45, QDOT=0.0, VDOT=0.0, COMP=0.0
LU JUNC,12, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,13, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,14, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,15, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,16, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,17, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,18, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,19, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,20, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,21, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,22, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,23, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,24, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,25, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,26, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,27, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,28, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,29, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,30, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
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LU JUNC,31, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
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LU JUNC,32, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,33, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,34, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,35, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,36, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,37, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,38, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,39, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,40, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,41, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,42, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,43, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,44, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,45, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,46, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,47, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,48, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU JUNC,49, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0,
QDOT=0.0
LU PLEN,50, TL=70.0, XL=1.0, PL=14.7, CX=0.0, CY=0.0, CZ=0.0
PA CONN,7,9,8, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=STUBE , TLEN=0.3433, DH=0.16667, AF=0.0218, WRF=3.0e-5
          , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
FD=0.0, FG=0.0
PA CONN,8,8,12, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=LOSS , FK=0.57, AF=0.0218, TPF=1.0

PA CONN,9,12,18, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=STUBE , TLEN=1.5883, DH=0.16667, AF=0.0218, WRF=3.0e-5
          , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
FD=0.0, FG=0.0
PA TUBE,10,11,15, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0
```

```
        , TLEN=2.854, DH=0.16667, AF=0.0218, WRF=3.0e-5, HC=0.0,
FC=0.0, FPOW=1.0
        , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,11,15,16, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=0.57, AF=0.0218, TPF=1.0

PA CONN,12,16,17, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=STUBE , TLEN=1.5, DH=0.16667, AF=0.0218, WRF=3.0e-5
           , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
FD=0.0, FG=0.0
PA CONN,13,18,13, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=0.38, AF=0.0218, TPF=1.0

PA CONN,14,17,13, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=1.14, AF=0.0218, TPF=1.0

PA TUBE,15,13,14, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0
        , TLEN=7.37, DH=0.16667, AF=0.0218, WRF=3.0e-5, HC=0.0,
FC=0.0, FPOW=1.0
        , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,16,14,19, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=0.57, AF=0.0218, TPF=1.0

PA TUBE,17,19,20, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0
        , TLEN=2.2183, DH=0.16667, AF=0.0218, WRF=3.0e-5, HC=0.0,
FC=0.0, FPOW=1.0
        , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,18,10,21, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=STUBE , TLEN=0.3433, DH=0.16667, AF=0.0218, WRF=3.0e-5
           , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
FD=0.0, FG=0.0
PA CONN,19,21,22, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=0.57, AF=0.0218, TPF=1.0

PA TUBE,20,22,23, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0
        , TLEN=8.9583, DH=0.16667, AF=0.0218, WRF=3.0e-5, HC=0.0,
FC=0.0, FPOW=1.0
        , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,21,23,24, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=0.57, AF=0.0218, TPF=1.0

PA TUBE,22,24,25, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0
        , TLEN=5.2817, DH=0.16667, AF=0.0218, WRF=3.0e-5, HC=0.0,
FC=0.0, FPOW=1.0
        , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,23,20,26, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
```

```
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=1.14, AF=0.0218, TPF=1.0

PA CONN,24,25,26, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=1.14, AF=0.0218, TPF=1.0

PA CONN,25,26,27, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=STUBE , TLEN=0.2133, DH=0.16667, AF=0.0218, WRF=3.0e-5
            , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
FD=0.0, FG=0.0
PA CONN,26,27,28, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=0.57, AF=0.0218, TPF=1.0

PA TUBE,27,28,29, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0
      , TLEN=1.9583, DH=0.16667, AF=0.0218, WRF=3.0e-5, HC=0.0,
FC=0.0, FPOW=1.0
      , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,28,29,30, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=0.57, AF=0.0218, TPF=1.0

PA CONN,29,30,31, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=STUBE , TLEN=0.5733, DH=0.16667, AF=0.0218, WRF=3.0e-5
            , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
FD=0.0, FG=0.0
PA CONN,30,31,32, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=0.57, AF=0.0218, TPF=1.0

PA CONN,31,32,33, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
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            , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
FD=0.0, FG=0.0
PA CONN,32,33,34, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=1.0, AF=0.0218, TPF=1.0

PA CONN,33,34,35, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=1.0, AF=0.0218, TPF=1.0

PA CONN,34,35,36, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=LOSS , FK=1.0, AF=0.0218, TPF=1.0

PA CONN,35,36,37, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
      DEV=STUBE , TLEN=0.166667, DH=0.16667, AF=0.0218, WRF=3.0e-5
            , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
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FD=0.0, FG=0.0
PA CONN,36,37,38, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=LOSS , FK=0.57, AF=0.0218, TPF=1.0

PA TUBE,37,38,39, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0
     , TLEN=4.70833, DH=0.16667, AF=0.0218, WRF=3.0e-5, HC=0.0,
FC=0.0, FPOW=1.0
     , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,38,39,40, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=LOSS , FK=0.57, AF=0.0218, TPF=1.0

PA TUBE,39,40,41, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0
     , TLEN=2.1092, DH=0.16667, AF=0.0218, WRF=3.0e-5, HC=0.0,
FC=0.0, FPOW=1.0
     , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,40,41,42, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=LOSS , FK=0.57, AF=0.0218, TPF=1.0

PA CONN,41,42,43, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=STUBE , TLEN=0.275833, DH=0.16667, AF=0.0218, WRF=3.0e-5
          , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
FD=0.0, FG=0.0
PA CONN,42,43,44, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=LOSS , FK=1.0, AF=0.0218, TPF=1.0

PA CONN,43,44,45, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=LOSS , FK=0.57, AF=0.0218, TPF=1.0

PA CONN,44,45,46, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=STUBE , TLEN=0.4533, DH=0.16667, AF=0.0218, WRF=3.0e-5
          , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
FD=0.0, FG=0.0
PA CONN,45,46,47, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=LOSS , FK=0.57, AF=0.0218, TPF=1.0

PA TUBE,46,47,48, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0
     , TLEN=3.35167, DH=0.16667, AF=0.0218, WRF=3.0e-5, HC=0.0,
FC=0.0, FPOW=1.0
     , AC=0.0, IPDC=1, UPF=0.5, AM=0.0, FD=0.0, FG=0.0
PA CONN,47,48,49, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=LOSS , FK=0.3, AF=0.0218, TPF=1.0

PA CONN,48,49,50, FR=0.0, STAT=VS, DUPI=1.0, DUPJ=1.0, EI=0.0,
EJ=0.0, DK=0.0, HK=0.0
     DEV=STUBE , TLEN=0.3275, DH=0.16667, AF=0.0218, WRF=3.0e-5
```

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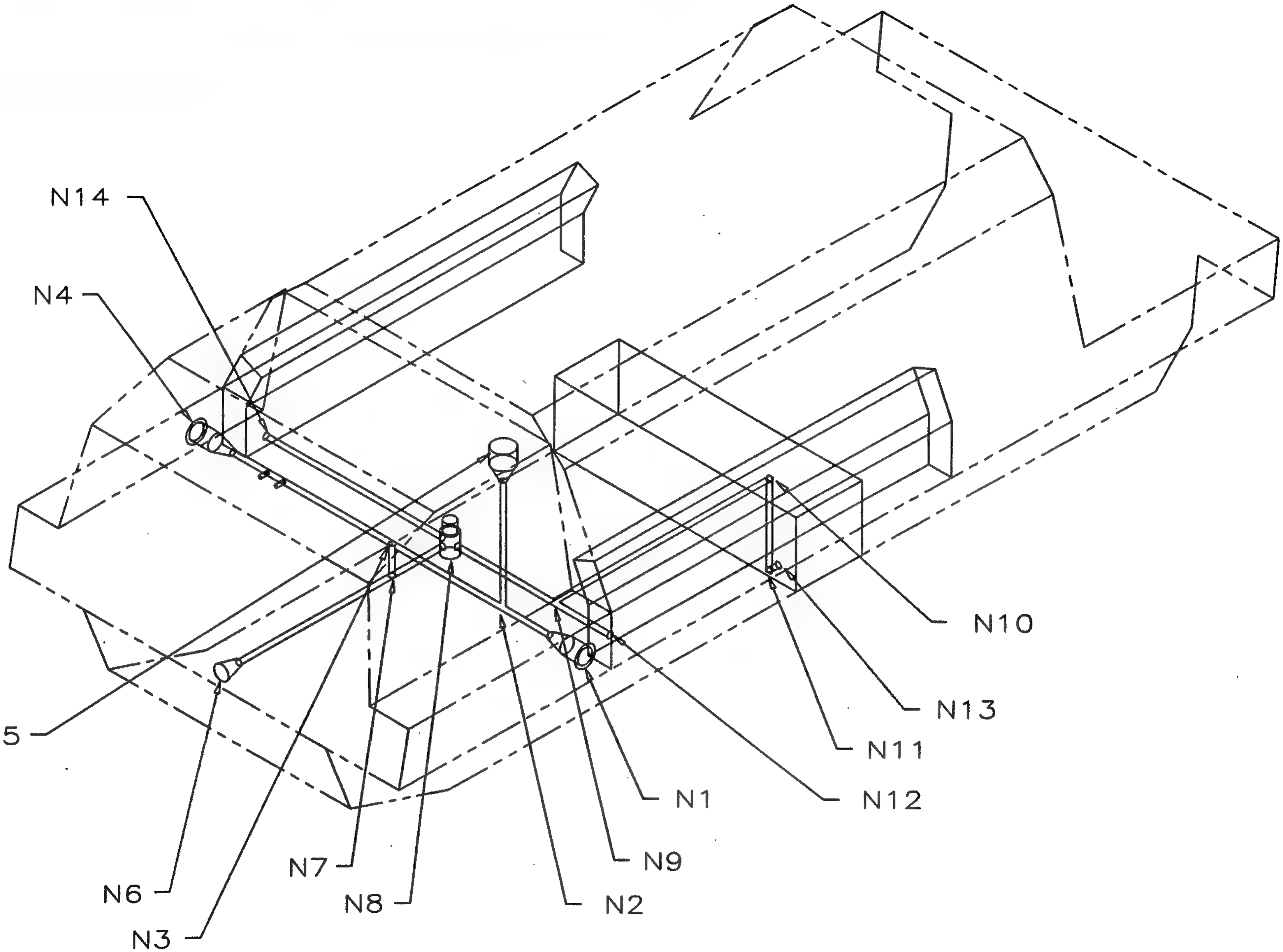
            , HC=0.0, FC=0.0, FPOW=1.0, AC=0.0, IPDC=1, UPF=0.5,
FD=0.0, FG=0.0
HEADER SUBROUTINE DATA

END OF DATA
```

APPENDIX A-SUPPLEMENTAL

PROOF OF CONCEPT

The following node charts and diagrams provide coordinate locations for each of the fuel system components. These dimension were used to analyze and optimize the fuel system layout.



FUEL STORAGE MODULE
FUEL LINES

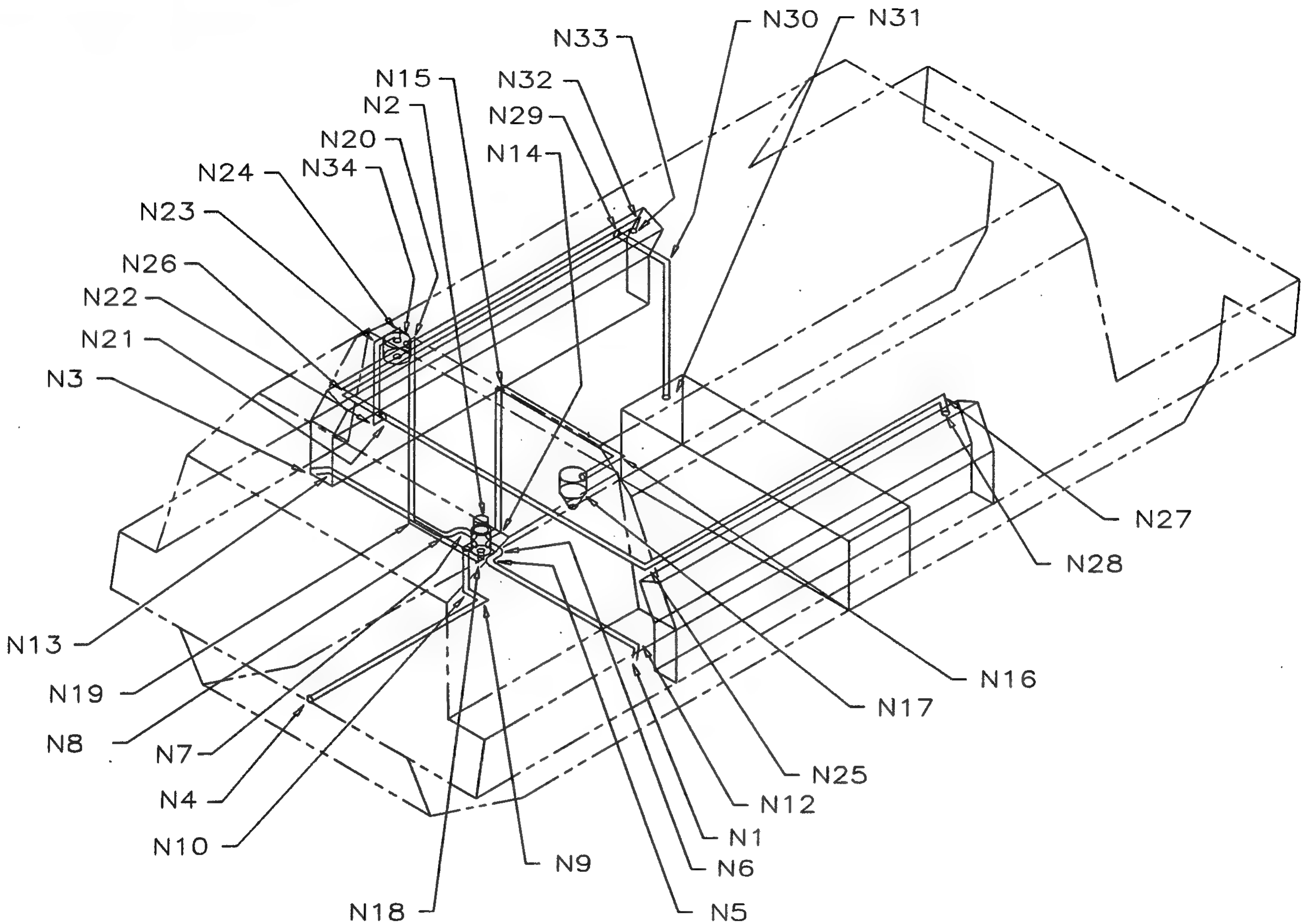
FUEL STORAGE MODULE - FUEL LINE NODES

N1	SARS RECEPTACLE, ROADSIDE	N8	REFUEL/DEFUEL VALVE
N2	TEE FITTING	N9	TEE FITTING
N3	TEE FITTING	N10	ELBOW, 90°
N4	SARS RECEPTACLE, CURBSIDE	N11	ELBOW, 90°
N5	MANUAL FILL PORT INLET	N12	VALVE, SHUT-OFF, TANK NO. 2
N6	AUTO RECEIVER INLET	N13	VALVE, SHUT-OFF, TANK NO. 1
N7	TEE FITTING	N14	VALVE, SHUT-OFF, TANK NO. 3

PIPE NO.	FROM NODE	TO NODE	LENGTH mm(in.)	PIPE SIZE	ELEVATION FROM "0" mm(in.) *
S1	N1	N2	720.8 (28.38)	2 IN.	0
S2	N2	N3	964.4 (37.97)	2 IN.	0
S3	N4	N3	1689.1 (66.35)	2 IN.	0
S4	N3	N7	238.3 (9.38)	2 IN.	0,-238.3 (0,-9.38)
S5	N7	N8	441.5 (17.38)	2 IN.	-238.3 (-9.38)
S6	N6	N7	1469.1 (57.84)	2 IN.	-238.3 (-9.38)
S7	N8	N14	1527 (60.12)	2 IN.	-238.3 (-9.38)
S8	N8	N9	835.2 (32.88)	2 IN.	-238.3 (-9.38)
S9	N9	N12	496.8 (19.56)	2 IN.	-238.3 (-9.38)
S10	N9	N10	1874.8 (73.81)	2 IN.	-238.3 (-9.38)

S11	N10	N11	687.3 (27.06)	2 IN.	-283.3, -925.6 (-9.38, -36.44)
S12	N11	N13	79.2 (3.12)	2 IN.	-925.6 (-36.44)

* VERTICAL HEIGHT FROM CENTERLINE OF SARS RECEPTACLE.



FUEL STORAGE MODULE
VENT LINES

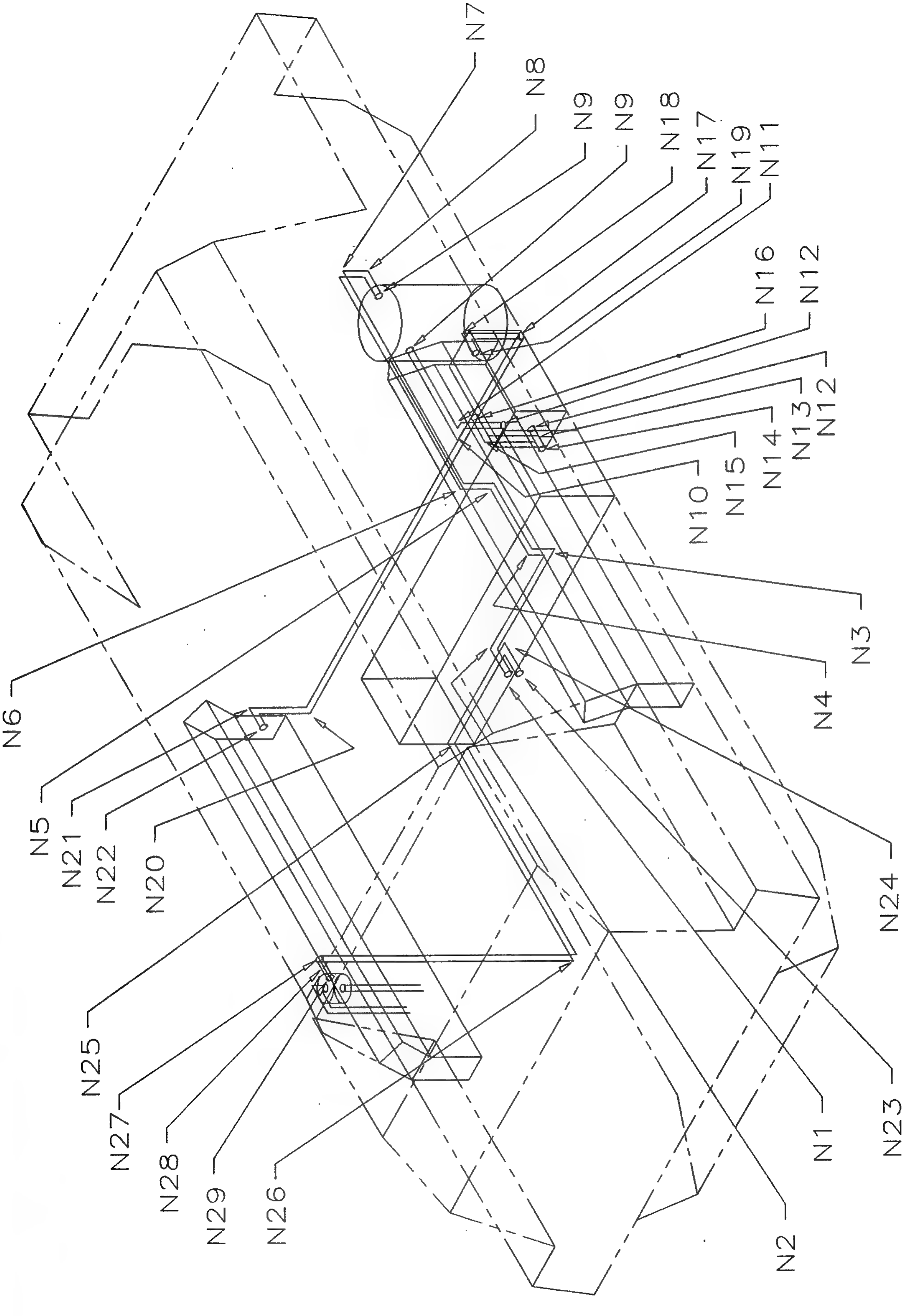
FUEL STORAGE MODULE - VENT LINE NODES

N1	SARS RECEPTACLE, ROADSIDE	N18	ELBOW, 90°
N2	SELECTOR VALVE	N19	ELBOW, 90°
N3	SARS RECEPTACLE, CURBSIDE	N20	TEE FITTING
N4	AUTO RECEIVER VENT	N21	TEE FITTING
N5	ELBOW, 90°	N22	ELBOW, 90°
N6	ELBOW, 90°	N23	ELBOW, 90°
N7	ELBOW, 90°	N24	ELBOW, 90°
N8	ELBOW, 90°	N25	ELBOW, 90°
N9	ELBOW, 90°	N26	ELBOW, 90°
N10	ELBOW, 90°	N27	ELBOW, 90°
N11	ELBOW, 90°	N28	CONNECTION TO TANK NO. 2
N12	ELBOW, 45°	N29	TEE FITTING
N13	ELBOW, 45°	N30	ELBOW, 90°
N14	ELBOW, 90°	N31	CONNECTION TO TANK NO. 1
N15	ELBOW, 90°	N32	ELBOW, 90°
N16	ELBOW, 90°	N33	CONNECTION TO TANK NO. 3
N17	MANUAL FILL PORT VENT	N34	FUEL/AIR SEPARATOR

PIPE NO.	FROM NODE	TO NODE	LENGTH mm(in.)	PIPE SIZE	ELEVATION FROM "0" mm(in.)
S1	N1	N12	99.8 (3.93)	2 IN.	0
S2	N12	N5	1021.6 (40.22)	2 IN.	0
S3	N5	N6	112.8 (5.44)	2 IN.	0
S4	N6	N2	124 (4.88)	2 IN.	0
S5	N3	N13	99.8 (3.93)	2 IN.	0
S6	N13	N8	1021.6 (40.22)	2 IN.	0
S7	N8	N7	112.8 (5.44)	2 IN.	0
S8	N7	N2	124 (4.88)	2 IN.	0
S9	N4	N9	1597.2 (62.88)	2 IN.	-335 (-13.19)
S10	N9	N10	157.2 (6.19)	2 IN.	-335 (-13.19)

S11	N10	N11	335 (13.19)	2 IN.	0, -335 (0, -13.19)
S12	N11	N2	76.2 (3.00)	2 IN.	0
S13	N2	N14	95.3 (3.75)	2 IN.	0
S14	N14	N15	1154.2 (45.44)	2 IN.	0,+1154.2 (0, +45.44)
S15	N15	N16	1120.6 (44.12)	2 IN.	+1154.2 (+45.44)
S16	N16	N17	338.1 (13.31)	2 IN.	+1154.2 (+45.44)
S17	N2	N18	84.1 (3.31)	2 IN.	-63.5, -147.6 (-2.50, -5.81)
S18	N18	N19	642.9 (25.31)	2 IN.	-147.6 (-5.81)
S19	N19	N20	1435.1 (56.50)	2 IN.	-147.6, +1287.5 (-5.81, +50.69)
S20	N20	N34	50.8 (2.00)	2 IN.	+1287.5 (+50.69)
S21	N34	N24	63.5 (2.50)	2 IN.	+1338.3, +1401.8 (+52.69, +55.19)
S22	N24	N23	174.8 (6.88)	2 IN.	+1401.8 (+55.19)
S23	N23	N22	596.9 (23.50)	2 IN.	+1401.8, +804.9 (+55.19, +31.69)
S24	N22	N21	65 (2.56)	2 IN.	+804.9 (+31.69)
S25	N21	N25	1609.8 (63.38)	2 IN.	+804.9 (+31.69)

S26	N25	N27	2730.5 (107.50)	2 IN.	+804.9 (+31.69)
S27	N27	N28	104.6 (4.12)	2 IN.	+804.9, +700 (+31.69, +27.56)
S28	N21	N26	676.1 (26.62)	2 IN.	+804.9 (+31.69)
S29	N26	N29	2246.4 (88.44)	2 IN.	+804.9 (+31.69)
S30	N29	N30	457.2 (18.00)	2 IN.	+804.9 (+31.69)
S31	N30	N31	869.9 (34.25)	2 IN.	+804.9, -65 (+31.69, -2.56)
S32	N29	N32	484.1 (19.06)	2 IN.	+804.9 (+31.69)
S33	N32	N33	104.6 (4.12)	2 IN.	+804.9, +700 (+31.69, +27.56)



FUEL TRANSFER MODULE

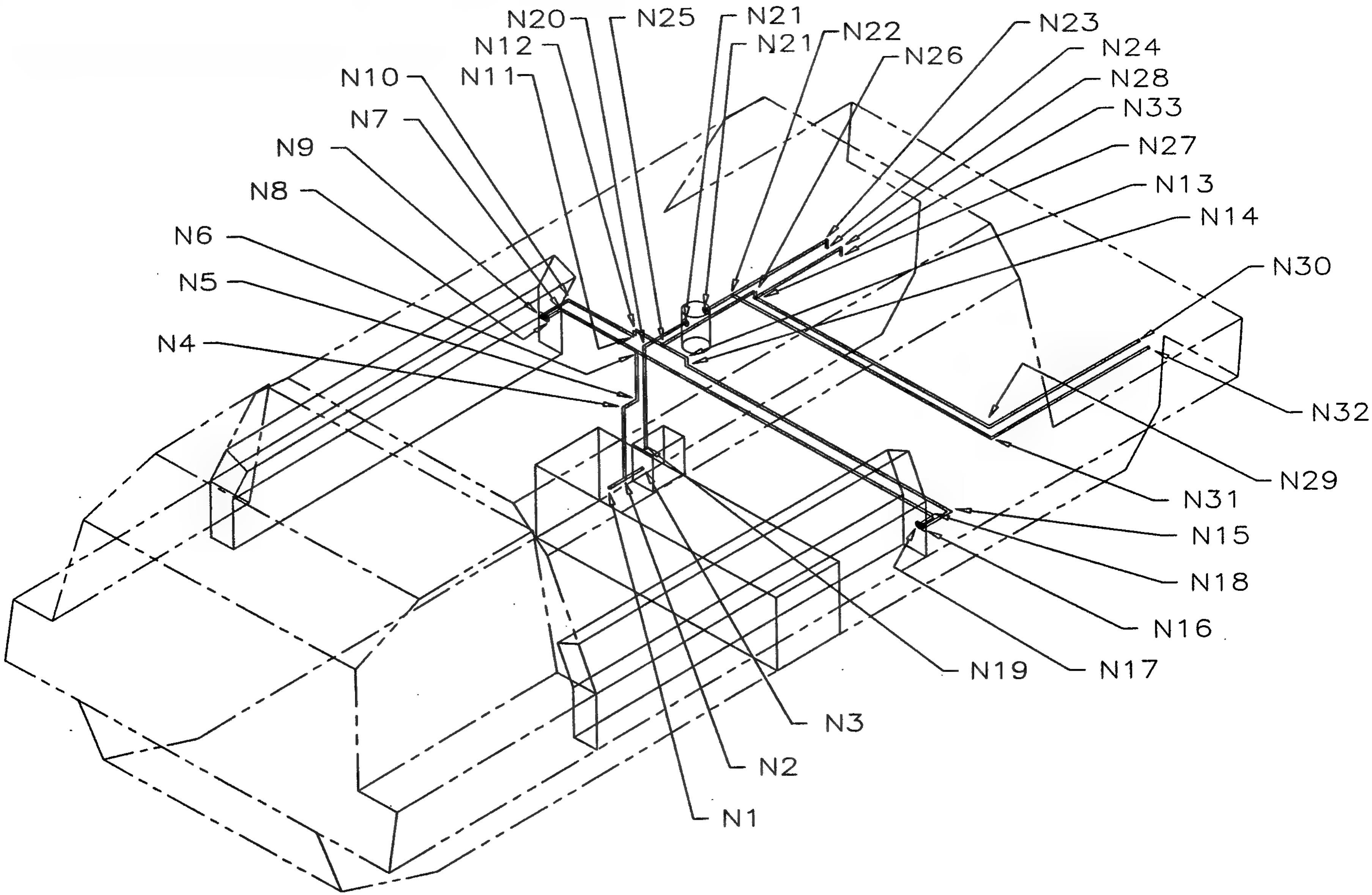
FUEL TRANSFER MODULE

- N1 CONNECTION TO TRANSFER BOOM, FUEL
- N2 ELBOW, 90°
- N3 ELBOW, 90°
- N4 ELBOW, 90°
- N5 ELBOW, 90°
- N6 ELBOW, 90°
- N7 ELBOW, 90°
- N8 ELBOW, 90°
- N9 FILTER/SEPARATOR
- N10 ELBOW, 90°
- N11 ELBOW, 90°
- N12 50 GPM PUMP
- N13 TEE FITTING
- N14 CONNECTION TO TANK 1
- N15 ELBOW, 90°
- N16 TEE FITTING
- N17 ELBOW, 90°
- N18 ELBOW, 90°
- N19 CONNECTION TO TANK 2
- N20 ELBOW, 90°
- N21 ELBOW, 90°
- N22 CONNECTION TO TANK 3
- N23 CONNECTION TO TRANSFER BOOM, VENT
- N24 ELBOW, 90°
- N25 ELBOW, 90°
- N26 ELBOW, 90°
- N27 ELBOW, 90°
- N28 TEE FITTING
- N29 FUEL/AIR SEPARATOR

PIPE NO.	FROM NODE	TO NODE	LENGTH mm(in.)	PIPE SIZE	ELEVATION FROM "0" mm(in.)
S1	N1	N2	211.1 (8.31)	2 IN.	-797.8 (-31.41)
S2	N2	N3	821.7 (32.35)	2 IN.	-797.8 (-31.41)
S3	N3	N4	143.8 (5.66)	2 IN.	-797.8, -628.7 (-31.41, -25.75)
S4	N4	N5	563.6 (22.19)	2 IN.	-628.7 (-25.75)
S5	N5	N6	225.6 (8.88)	2 IN.	-628.7, -428.8 (-25.75, -16.88)
S6	N6	N7	1800.4 (70.88)	2 IN.	-428.8 (-16.88)
S7	N7	N8	187.5 (7.38)	2 IN.	-428.8, -616 (-16.88, -24.25)
S8	N8	N9	187.9 (7.40)	2 IN.	-616 (-24.25)

S9	N9	N10	717.6 (28.25)	2 IN.	-616 (-24.25)
S10	N10	N11	76.2 (3.00)	2 IN.	-616 (-24.25)
S11	N11	N12	300 (11.81)	2 IN.	-616, -916 (-24.25, -36.06)
S12	N14	N13	82.6 (3.25)	2 IN.	-925.6 (-36.44)
S13	N13	N12	82.6 (3.25)	2 IN.	-925.6 (-36.44)
S14	N13	N15	368.3 (14.50)	2 IN.	-925.6, -557.3 (-36.44, -21.94)
S15	N15	N16	182.6 (7.19)	2 IN.	-557.3 (-21.94)
S16	N16	N17	195 (27.12)	2 IN.	-557.3 (-21.94)
S17	N17	N18	403.4 (15.88)	2 IN.	-557.3, -153.9 (-21.94, -6.06)
S18	N18	N19	139.7 (5.50)	2 IN.	-153.9 (-6.06)
S19	N16	N20	2489.2 (98.00)	2 IN.	-557.3 (-21.94)
S20	N20	N21	403.4 (15.88)	2 IN.	-557.3, -153.9 (-21.94, -6.06)
S21	N21	N22	139.7 (5.50)	2 IN.	-153.9 (-6.06)
S22	N23	N24	211.1 (8.31)	2 IN.	-614.4 (-24.19)
S23	N24	N25	800.1 (31.50)	2 IN.	-614.4 (-24.19)
S24	N25	N26	1928.1 (75.91)	2 IN.	-614.4 (-24.19)

S25	N26	N27	1901.9 (74.88)	2 IN.	-614.4, +1287.5 (-24.19, +50.69)
S26	N27	N29	88.9 (3.50)	2 IN.	+1287.5 (+50.69)



VEHICLE FUEL MODULE

VEHICLE FUEL MODULE

N1	CONNECTION TO TANK 1, SUPPLY	N17	CONNECTION TO TANK 2, SUPPLY
N2	VALVE, SELECTOR	N18	ELBOW, 90°
N3	CONNECTION TO PUMP, INLET	N19	CONNECTION TO PUMP, OUTLET
N4	ELBOW, 90°	N20	ELBOW, 90°
N5	ELBOW, 90°	N21	FILTER/SEPARATOR
N6	VALVE, SELECTOR	N22	VALVE, SELECTOR, SUPPLY
N7	ELBOW, 90°	N23	ELBOW, 90°
N8	CONNECTION TO TANK 3, SUPPLY	N24	CONNECTION TO ENGINE, SUPPLY
N9	CONNECTION TO TANK 3, RETURN	N25	TEE FITTING
N10	ELBOW, 90°	N26	ELBOW, 90°
N11	ELBOW, 90°	N27	VALVE, SELECTOR, RETURN
N12	ELBOW, 90°	N28	CONNECTION TO ENGINE, RETURN
N13	ELBOW, 90°	N29	ELBOW, 90°
N14	ELBOW, 90°	N30	CONNECTION TO APU, RETURN
N15	ELBOW, 90°	N31	ELBOW, 90°
N16	CONNECTION TO TANK 2, RETURN	N32	CONNECTION TO APU, SUPPLY

PIPE NO.	FROM NODE	TO NODE	LENGTH mm(in.)	PIPE SIZE	ELEVATION FROM "0" mm(in.)
S1	N1	N2	133.4 (5.25)	3/4 IN.	-925.6 (-36.44)
S2	N2	N3	160.3 (6.31)	3/4 IN.	-925.6 (-36.44)
S3	N4	N2	541.3 (21.31)	3/4 IN.	-925.6, -384 (-36.44, -15.12)
S4	N4	N5	122.2 (4.81)	3/4 IN.	-384 (-15.12)
S5	N6	N5	376.2 (14.81)	3/4 IN.	-384, -7.9 (-15.12, -.31)
S6	N7	N6	655.5 (25.81)	3/4 IN.	-7.9 (-.31)
S7	N8	N7	131.8 (5.19)	3/4 IN.	-7.9 (-.31)
S8	N6	N18	2578.1 (101.50)	3/4 IN.	-7.9 (-.31)
S9	N18	N17	131.8 (5.19)	3/4 IN.	-7.9 (-.31)

S10	N9	N10	236.5 (9.31)	3/4 IN.	-7.9 (-.31)
S11	N10	N11	574.5 (22.62)	3/4 IN.	-7.9 (-.31)
S12	N11	N12	53.1 (2.09)	3/4 IN.	-7.9, +44.5 (-.31, +1.75)
S13	N12	N25	234.7 (9.62)	3/4 IN.	+44.5 (+1.75)
S14	N25	N13	209.6 (8.25)	3/4 IN.	+44.5 (+1.75)
S15	N13	N14	53.1 (2.09)	3/4 IN.	+44.5, -7.9 (+1.75, -.31)
S16	N14	N15	2281.2 (89.81)	3/4 IN.	-7.9 (-.31)
S17	N15	N16	236.5 (9.31)	3/4 IN.	-7.9 (-.31)
S18	N19	N20	777.7 (30.62)	3/4 IN.	-46.7, -7.9 (-1.84, -.31)
S19	N20	N21	368.3 (14.50)	3/4 IN.	-7.9 (-.31)
S20	N21	N22	238.3 (9.38)	3/4 IN.	-7.9 (-.31)
S21	N22	N23	828.5 (32.62)	3/4 IN.	-7.9 (-.31)
S22	N23	N24	53.1 (2.09)	3/4 IN.	-7.9, -61 (-.31, -2.40)
S23	N22	N31	2241.6 (88.25)	3/4 IN.	-7.9 (-.31)
S24	N31	N32	1366.8 (53.81)	3/4 IN.	-7.9 (-.31)
S25	N25	N26	822.5 (32.38)	3/4 IN.	44.5 (+1.75)

S26	N26	N27	53.1 (2.09)	3/4 IN.	+44.5, -7.9 (+1.75, -.31)
S27	N27	N28	754.1 (29.69)	3/4 IN.	-7.9 (-.31)
S28	N28	N33	53.1 (2.09)	3/4 IN.	-7.9, -61 (-.31, -2.40)
S29	N27	N29	2025.7 (79.75)	3/4 IN.	-7.9 (-.31)
S30	N29	N30	1301.8 (51.25)	3/4 IN.	-7.9 (-.31)

APPENDIX B

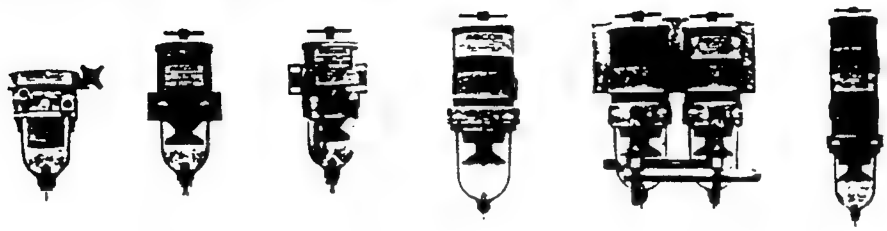
COMPONENTRY

B.1 INTRODUCTION

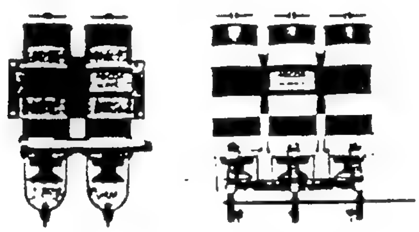
This section contains vendor information on possible FARV Fuel System components. These items have been selected as examples of items that reflect the requirements of Section Four. Inclusion of these examples is not intended as an endorsement or recommendation of the use of these items over other, more suitable, components that may be available.

The following pages are applicable to the VFM Filter/Separator (Ref. Section Four, paragraph 4.3.2.1):

FUEL FILTER/WATER SEPARATORS



200FG 500FG 500FG S/S 900FG 75/900FG 1000FG



73/1000FG
75/1000FG

79/1000FG
77/1000FG

Turbine Series

Model #	500	900	1000	75/900	73/1000[1]	75/1000[2]	77/1000[3]	79/1000[4]
Max. Flow Rate	60 gph (227 lph)	90 gph (341 lph)	180 gph (681 lph)	90/180 gph (341/681 lph)	360 gph (1363 lph)	180/360 gph (681/1363 lph)	540 gph (2044 lph)	360/540 gph (1363/2044 lph)
Height	13" (330 mm)	17" (432mm)	22" (559mm)	17" (432mm)	22" (559mm)	22" (559mm)	22" (559mm)	22" (559mm)
Width	6" (152mm)	6" (152mm)	6" (152mm)	16" (406mm)	16" (406mm)	16" (406mm)	23" (584mm)	23" (584mm)
Depth	6" (152mm)	7" (178mm)	7" (178mm)	10" (254mm)	9" (229mm)	10" (254mm)	9" (229mm)	10" (254mm)
Weight	4 lbs (2kg)	6 lbs (3kg)	10 lbs (5kg)	23 lbs (10kg)	25 lbs (11kg)	25 lbs (11kg)	32 lbs (15kg)	32 lbs (15kg)
Port Size	9/16"-18 UNF (14mm x 1.5)	7/8"-14 UNF (22mm x 1.5)	7/8"-14 UNF (22mm x 1.5)	3/4" NPT	3/4" NPT	3/4" NPT	3/4" NPT	3/4" NPT
Clean Vacuum Drop	1.25 inHg (4.23 kPa)	1.5 inHg (5.1 kPa)	3.0 inHg (10.1 kPa)	2.0 inHg (6.8 kPa)	3.5 inHg (11.8 kPa)	5.0 inHg (16.9 kPa)	3.5 inHg (11.8 kPa)	5.0 inHg (16.9 kPa)
Proof (test) Pressure	100 psi (689 kPa)	100 psi (689 kPa)	100 psi (689 kPa)	100 psi (689 kPa)	100 psi (689 kPa)	100 psi (689 kPa)	100 psi (689 kPa)	100 psi (689 kPa)
Maximum Vacuum	28.5 inHg (96.3 kPa)	28.5 inHg (96.3 kPa)	28.5 inHg (96.3 kPa)	28.5 inHg (96.3 kPa)	28.5 inHg (96.3 kPa)	28.5 inHg (96.3 kPa)	28.5 inHg (96.3 kPa)	28.5 inHg (96.3 kPa)
Element #	2010SM-OR	2040SM-OR	2020SM-OR	2040SM-OR	2020SM-OR	2020SM-OR	2020SM-OR	2020SM-OR
Material	Resin Impregnated Cellulose				Resin Impregnated Cellulose			
Dirt Capacity (AC Fine Dust)	10gm	150gm	400gm	300gm	600gm	800gm	1200gm	1200gm
Dirt Removal Rating	96% @ 2 micron				96% @ 2 micron			
Removal Clearance	4" (102mm)	5" (127mm)	10" (254mm)	5" (127mm)	10" (254mm)	10" (254mm)	10" (254mm)	10" (254mm)
Water Removal Efficiency	less than 10 ppm free water				less than 10 ppm free water			
Temperature Rating	-50/255°F (-46/107°C)				-50/255°F (-46/107°C)			

1 Model 73-1000 w/o shutoff valves 2 Model 75-1000 w/ shutoff valves 3 Model 77-1000 w/o shutoff valves 4 Model 79-1000 w/ shutoff valves

900/1000 SERIES TURBINE FUEL FILTER/WATER SEPARATORS

MODEL #	DESCRIPTION		CASE QUANTITY	UNIT PRICE
900FG	Fuel Filter/Separator w/See-thru Bowl		4	$178 70
1000FG	Fuel Filter/Separator w/See-thru Bowl		4	208 45
	Options — Add the following suffix to 900FG or 1000FG:			
	M Metal Bowl	900FGM	4	184.30
		1000FGM	4	214 10
	P See-thru Bowl w/Water Sensor Probes	900FGP	4	186 60
		1000FGP	4	216.30
	12 or 24 In-filter Heater, 150 Watt	900FG12	4	232 60
		900FG24	4	238.20
		1000FG12	4	262.40
		1000FG24	4	268 00
	312 or 324 In-filter Heater, 300 Watt	900FG312	4	245 80
		900FG324	4	251.40
		1000FG312	4	275.60
		1000FG324	4	281.20
	P12 or P24 See-thru Bowl w/	900FGP12	4	240.50
	Water Sensor Probes	900FGP24	4	246 10
	and In-filter Heater, 150 Watt	1000FGP12	4	270 25
		1000FGP24	4	275.90

900 AND 1000 SERIES PARTS LIST

(Diagram on Page 9.)

ITEM NO.	PART #	DESCRIPTION	CASE QUANTITY	UNIT PRICE
1	RK 11888	T-Handle (FF/FG)	1	$ 14 90
2a	11350	T-Handle O-Ring (FG)	10	60
2b	11003	T-Handle Gasket, Nylon (FE/FF)	10	1.00
2c	11004	T-Handle Gasket, Tetra (FE/FF)	10	1.00
3a	RK 11005B	Lid (FG)	1	26.45
3b	RK 11005/A	Lid, T-Handle and O-Ring (FE/FF)	1	42.00
4a	RK 19001	Return Tube (900 FE/FF/FG)	1	20.90
4b	RK 11008	Return Tube (1000 FE/FF/FG)	1	23.60
5a	RK 19002	Outer Cylinder (900 FE/FF/FG)	1	19.40
5b	RK 11021	Outer Cylinder (1000 FE/FF/FG)	1	27.70
6a	RK 11-1556	12V Heater w/See-thru Bowl (FF/FG) (Bullet type feed-thru terminals)	1	104.20
6b	RK 11585	12V Heater (FE/FF/FG) (Bullet type feed-thru terminals)	1	65.50
6c	RK 11861	12V Heater Relay (FE/FF/FG)	1	58.10
6d	RK 11-1671-01	12V Heater (Base feed-thru type)	1	65.50
6e	RK 21067	Heater/Feed thru Assembly (Base feed-thru)	1	22.30
7a	RK 11-1557	24V Heater w/See-thru Bowl item (FF/FG) (Bullet type feed-thru terminals)	1	109 80
7b	RK 11586	24V Heater (FE/FF/FG) (Bullet type feed-thru terminals)	1	71 10
7c	RK 11862	24V Heater Relay (FE/FF/FG)	1	64 00
7d	RK 11-1671-02	24V Heater (Base feed-thru type)	1	71 10
8	RK 11-1678	Base and (4) Self-tapping Screws (includes provision for optional heater feed-thru) (FF/FG)	1	55 10
10	RK 11542	Capscrew, (4 Each) Thrd. Frmg. ¼" — 20×1" long (FE/FF/FG)	1	3.20
11	RK 11028B	Check Ball and Gasket (FG	10	5 50

900 AND 1000 SERIES PARTS LIST (Continued)

(Diagram on Page 9.)

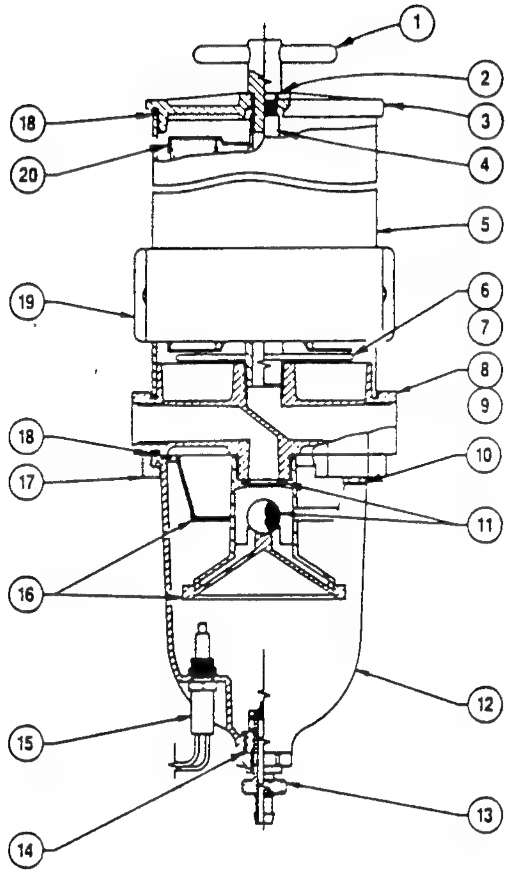
ITEM NO.	PART #	DESCRIPTION	CASE QUANTITY	UNIT PRICE
12a	RK 11-1606	See-thru Bowl (plugged probe hole)	1	$ 28.00
12b	RK 11-1551	See-thru Bowl, 5" diameter (FF/FG)	1	28 00
12c	RK 11-1553	See-thru Bowl w/Water Sensor Probes (Bullet type feed-thru terminals) (FF/FG)	1	38.70
12d	RK 11-1555	See-thru Bowl w/Two Heater Terminals (Bullet type feed-thru terminals) (FF/FG)	1	38.70
12e	RK 11-1559	See-thru Bowl w/Two Heater Terminals and Two Water Sensor Probes (Bullet type feed-thru terminals) (FF/FG)	1	49 30
12f	RK 11741	Probe/Terminal Kit for See-thru Bowl (Bullet-type)	1	5 60
12g	RK 11734	Metal Bowl (FG)	1	35.90
12h	RK 11-1397	Metal Bowl w/Water Sensor Probes (FF/FG)	1	77 90
12i	RK 11-1613	Metal Bowl w/Two Heater Terminals (FF/FG)	1	63.80
12j	RK 11972	Probe/Terminal Kit for Metal Bowl (Bullet-type)	1	21.00
12k	RK 11-1699	See-thru Bowl w/Bowl Heater Feed thru	1	28 00
13a	RK 11780	Drain Valve (FF/FG)	10	15 60
13b	RK 11746	Seals for Drain Valve #11780	1	3.00
13c	11040	Bowl Drain Fitting (FE/FF/MA)	10	6.30
13d	RK 11042	¼" Brass Petcock Drain	1	10.00
13e	11369	Brass Fitting, ¼" MNPT × ⅛" FNPT	1	3.30
14	RK 11341	Bowl Drain Gasket #11041 and O-Ring #11340 (FE/FF/FG)	10	2.70
15	RK 21069	Water Sensor Probe, O-Ring & Connector	1	22.30
16	RK 11026D	Turbine Centrifuge and Conical Baffle w/Seals (FG)	1	55.10
17a	RK 11037A	Bowl Ring, 5" diameter (FF/FG)	1	30.40
17b	RK 11037	Bowl Ring, 4" diameter (FE)	1	42.50
18a	11007	5" Gasket (FE/FF/FG)	10	1.20
18b	11036	Bowl O-Ring (FE)	10	4.00
19a	RK 11815-101	Mounting Bracket Single Hole (FG)	1	16.40
19c	RK 11838	5/16" Carriage Bolt (FG)	10	1.80
19d	11841	5/16" Hex Nut (FG)	10	.85
19e	RK 11043	Steel Mounting Bracket (FE/FF)	1	19.00
21	RK 11-1518	Frame Rail Mounting Bracket	1	34.00
	RK 11-1404	Complete Seal Service Kit	1	13.80
	11548	Spin-on Cap Assembly	1	14.60

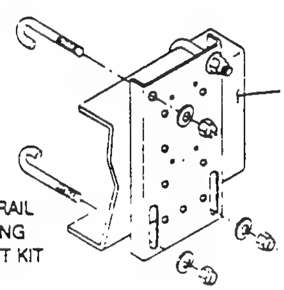
The selection of a Racor filter element depends on the engine, the demands of the operating environment, and the customer maintenance requirements.

*20	2040PM-OR	Primary w/O-Rings Replacement Element	20	10 00
*20	2040SM-OR	Secondary (Final) w/O-Rings Replacement Element	20	10 00
*20	2020PM-OR	Primary w/O-Rings Replacement Element	10	12.10
*20	2020SM-OR	Secondary (Final) w/O-Rings Replacement Element	10	12.10
*20	2020TM-OR	Severe Service w/O-Rings Replacement Element	10	12.10

* Racor primary filters should be chosen to enhance an engine's secondary (final) filter in order to maximize life and efficiency. Racor secondary (final) filters should be chosen depending upon the above conditions and the particular injection system they are protecting.

900/1000 SERIES FUEL FILTER/WATER SEPARATORS





21 FRAME RAIL MOUNTING BRACKET KIT

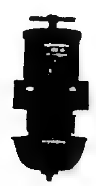
900/1000 SERIES CUTAWAY VIEW
CIRCLED NUMBER CORRESPONDS TO THE ITEM NO.
SHOWN IN THE PARTS LIST ON PAGES 7 AND 8.

MARINE FILTER/SEPARATORS

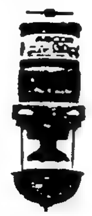
Racor Fuel Filter/Water Separators for marine use have passed rugged Fire and Thermal Shock tests, and Racor offers

Marine U.L.-listed and U.S. Coast Guard accepted filter/separator with either a see-through or metal bowl. There is a

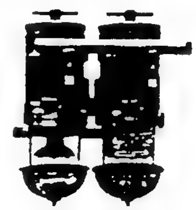
Racor Fuel Filter/Water Separator for every marine engine application, including multiple units that can be serviced during continuous operation.



500MA

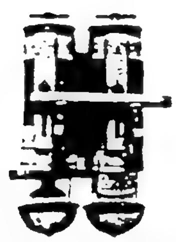


900MA

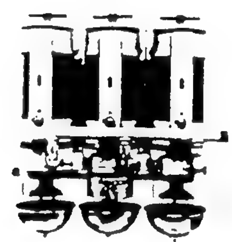


75/900MA
75/900MAV*

1000MA



75/1000MA*
73/1000MA
75/1000MAV*



77/1000MA
79/1000MA*

*Please see NOTES on page 49.

TURBINE SERIES

GASOLINE OR DIESEL UL-LISTED USCG ACCEPTED								
DIESEL ONLY UL-LISTED USCG ACCEPTED SEE-THRU BOWL W/ METAL SHIELD								
DIESEL ONLY UL-LISTED SEE-THRU BOWL W/METAL SHIELD				75/900MAV*		75/1000MAV*		
	500MA	900MA	1000MA	75/900MA*	73/1000MA*	75/1000MA*	77/1000MA*	79/1000MA*
ALL-METAL BOWL	500MAM	900MAM	1000MAM	75/900MAM*	73/1000MAM*	75/1000MAM*	77/1000MAM*	79/1000MAM*
Maximum Flow Rate	60 gph 227 lph	90 gph 341 lph	180 gph 681 lph	180 gph 681 lph	360 gph 1363 lph	180/360 gph 681/1363 lph	540 gph 2044 lph	360/540 gph 1363/2044 lph
Height	13"/330 mm	17"/432 mm	22"/559 mm	17"/432 mm	22"/559 mm	22"/559 mm	22"/559 mm	22"/559 mm
Width	6"/152 mm	6"/152 mm	6"/152 mm	16"/406 mm	16"/406 mm	16"/406 mm	23"/584 mm	23"/584 mm
Depth*	6"/152 mm	7"/178 mm	7"/178 mm	10"/254 mm	9"/229 mm	10"/254 mm	9"/229 mm	10"/254 mm
Weight	4 lbs/2 kg	9 lbs/4 kg	[illegible] lbs/5 kg	22 lbs/10 kg	25 lbs/11 kg	25 lbs/11 kg	32 lbs/15 kg	32 lbs/15 kg
Port Size	9/16"-18UNF 14 mm x 1.5	7/8"-14 UNF 22 mm x 1.5	7/8"-14 UNF 22 mm x 1.5	3/4" NPT	3/4" NPT	3/4" NPT	3/4" NPT	3/4" NPT
Clean Vacuum Drop	1.25 in Hg 4.23 kPa	1.5 in Hg 5.1 kPa	3.0 in Hg 10.1 kPa	2.0 in Hg 6.8 kPa	3.5 in Hg 11.8 kPa	5.0 in Hg 16.9 kPa	3.5 in Hg 11.9 kPa	5.0 in Hg 16.9 kPa
Maximum Operating Pressure	100 psi 689 kPa	100 psi 689 kPa	100 psi 689 kPa	100 psi 689 kPa	100 psi 689 kPa	100 psi 689 kPa	100 psi 689 kPa	100 psi 689 kPa
Element #	2010SM	2040SM	2020SM	2040SM	2020SM	2020SM	2020SM	2020SM
Element Removal Clearance	4"/102 mm	5"/127 mm	10"/254 mm	5"/127 mm	10"/254 mm	10"/254 mm	10"/254 mm	10"/254 mm

900/1000 SERIES TURBINE FUEL FILTER/WATER SEPARATORS

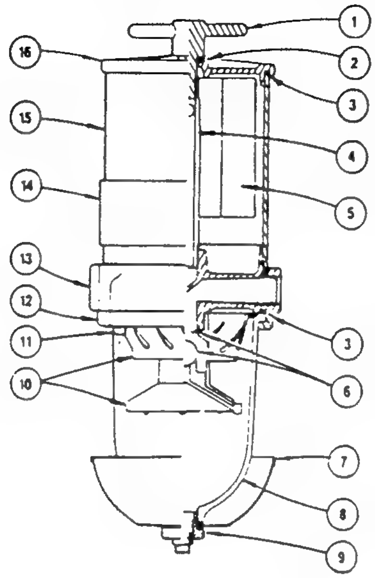
MODEL #	DESCRIPTION	CASE QUANTITY	UNIT PRICE
900MA	Fuel Filter/Water Separator, See-thru Bowl for Marine Diesel Applications. UL Listed and USCG Accepted	4	$214.65
900MAM	Fuel Filter/Water Separator, Metal Bowl for Marine Diesel or Gasoline Applications. UL Listed and USCG Accepted	4	219.95
1000MA	Fuel Filter/Water Separator, See-thru Bowl for Marine Diesel Applications. UL Listed and USCG Accepted	4	250.60
1000MAM	Fuel Filter/Water Separator, Metal Bowl for Marine Diesel or Gasoline Applications. UL Listed and USCG Accepted	4	255.90

900 AND 1000 SERIES PARTS LIST

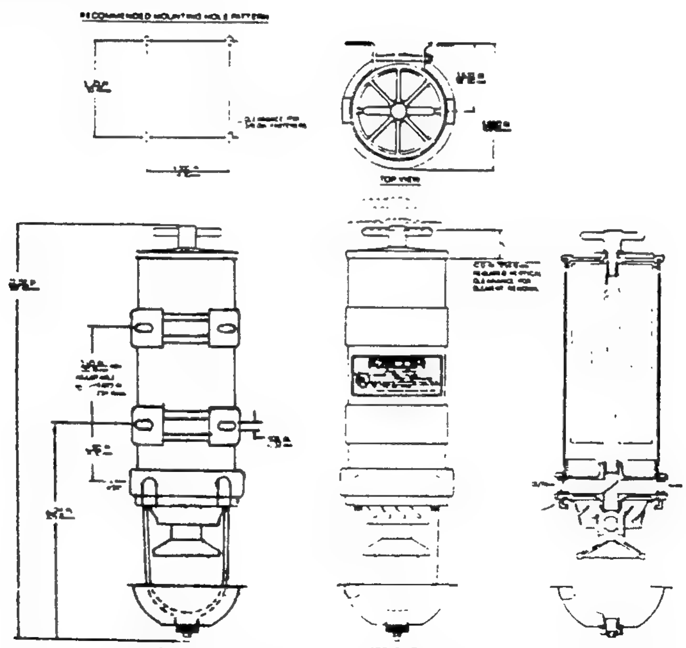
(Diagram on Page 52.)

ITEM NO.	PART #	DESCRIPTION	CASE QUANTITY	UNIT PRICE
1	RK 11888	T-Handle	1	$ 14.90
2	11350	T-Handle O-Ring	10	.60
3	11007	5" Gasket	10	1.20
4a	RK 19001	Return Tube, 900	1	20.90
4b	RK 11008	Return Tube, 1000	1	23.60
5	2040PM-OR	Primary w/O-Rings Replacement Element	20	10.00
5	2040SM-OR	Secondary (Final) w/O-Rings Replacement Element	20	10.00
5	2020PM-OR	Primary w/O-Rings Replacement Element	10	12.10
5	2020SM	Secondary (Final) Replacement Element	10	11.30
5	2020SM-OR	Secondary (Final) w/O-Rings Replacement Element	10	12.10
5	2020TM-OR	Severe Service w/O-Rings Replacement Element	10	12.10
6	RK 11028B	Check Ball and Gasket	10	5.50
7	RK 11868	Heat Deflector	1	31.40
8	RK 11-1551	See-thru Bowl, 5" diameter	1	28.00
9a	11040	Bowl Drain Fitting	10	6.30
9b	RK 11341	Bowl Drain Gasket #11041 and O-Ring #11340	10	2.70
9c	RK 11042	¼" Brass Petcock Drain	1	10.00
10	RK 11026D	Turbine Centrifuge and Conical Baffle w/Seals	1	34.30
11	RK 11542	Capscrew (4 each) Thrd. Frmg. ¼" — 20×1" long	1	3.20
12	RK 11037A	Bowl Ring, 5" diameter (MA)	1	30.40
13	RK 11023A/B	Base and (4) Self-tapping Screws	1	55.10
14a	RK 11815-101	Mounting Bracket Single Hole	1	16.40
14b	RK 11838	5/16" Carriage Bolt	10	1.80
14c	11841	5/16" Hex Nut	10	.85
15a	RK 19002	Outer Cylinder, 900	1	19.40
15b	RK 11021	Outer Cylinder, 1000	1	27.70
16	RK 11005B	Lid	1	26.45
	RK 11-1404	Complete Seal Service Kit	1	13.80

900/1000 SERIES MARINE TURBINE FUEL FILTERS/WATER SEPARATORS

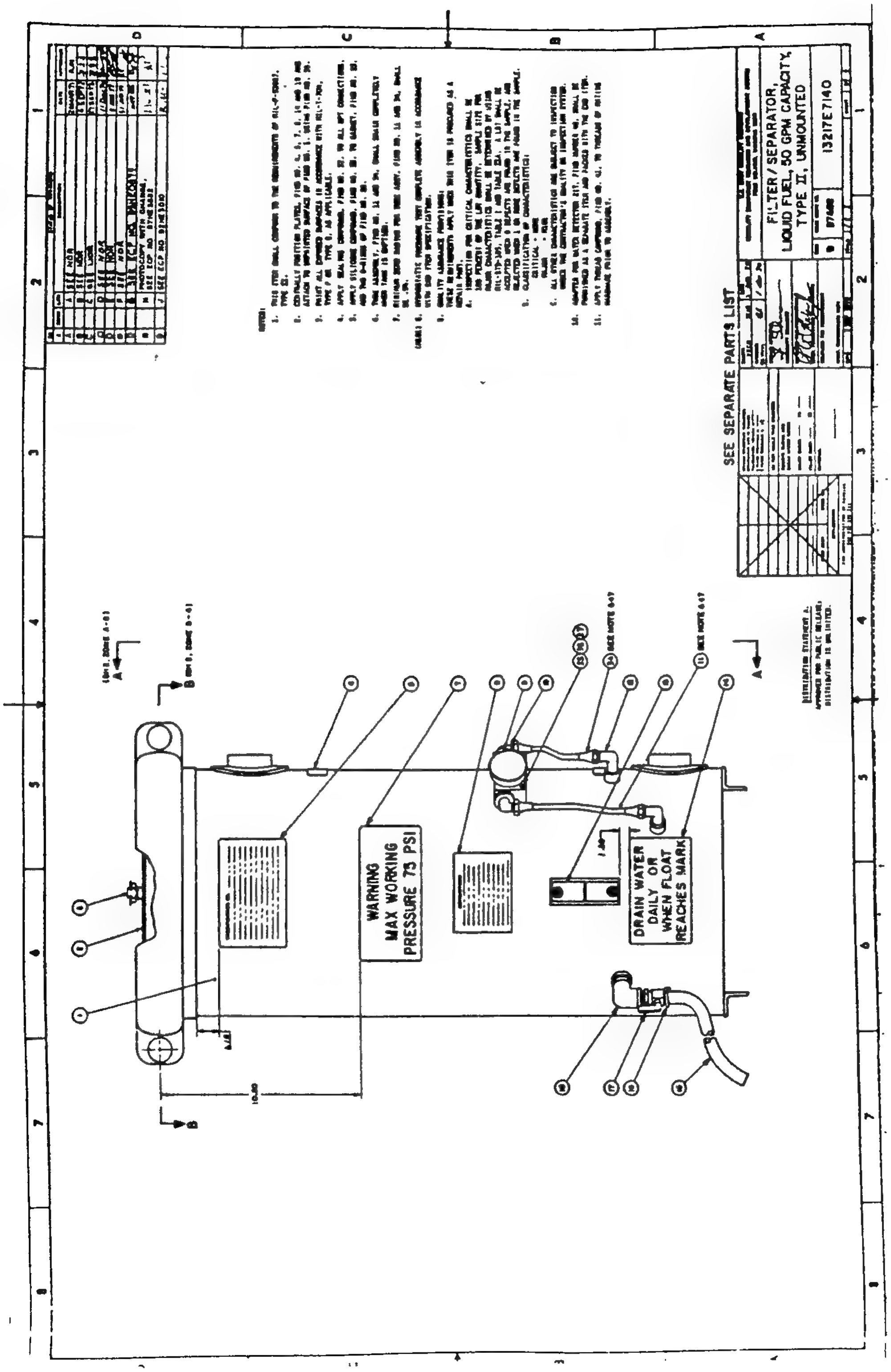


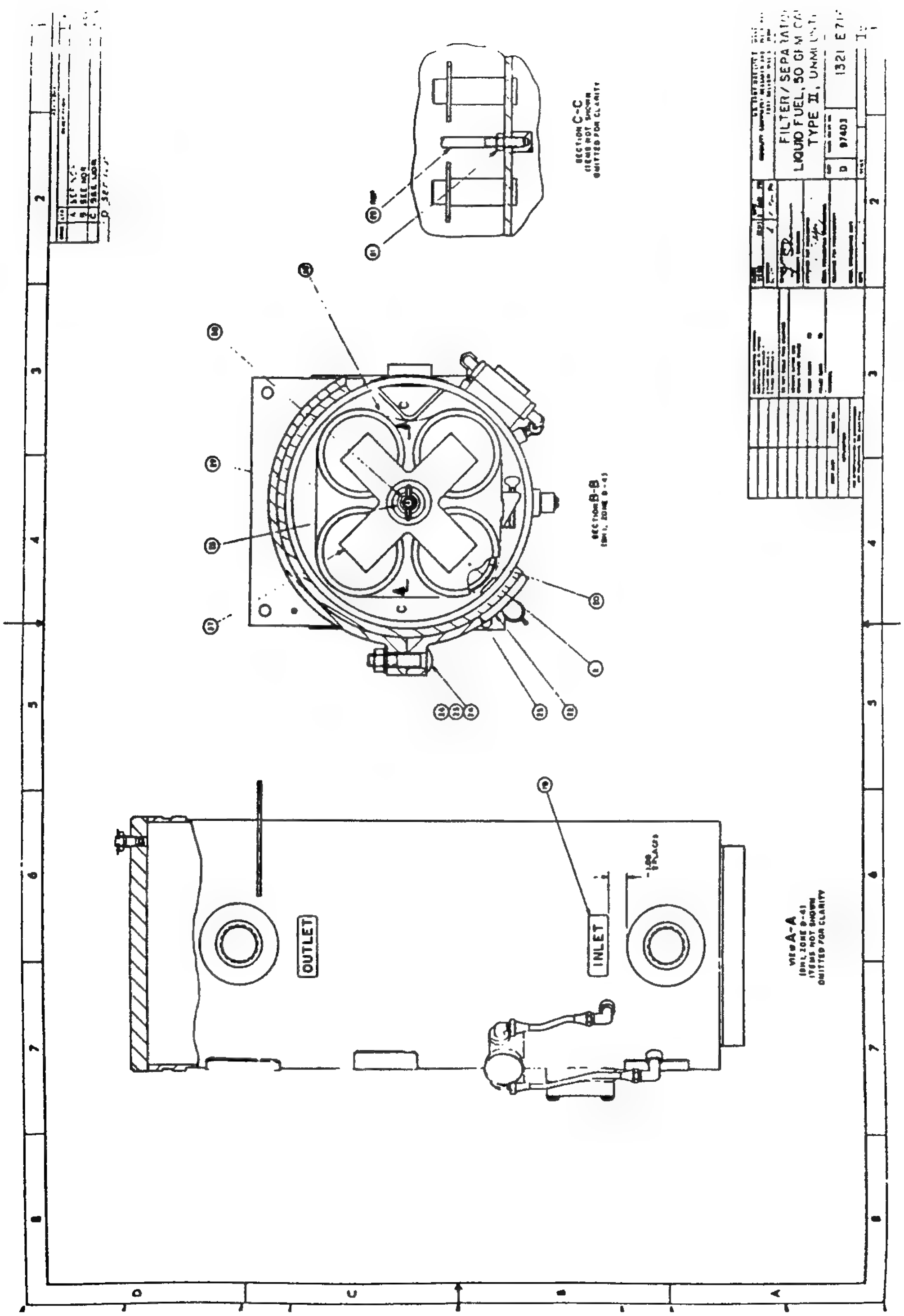
Model 1000MA



Port threads are NOT suitable for pipe fittings. See fittings chart for appropriate fittings

The following pages are applicable to the FTM Filter/Separator (Ref. Section Four, paragraph 4.4.2.1):




OUTLET
INLET
VIEW A-A
SECTION B-B
SECTION C-C
FILTER/SEPARATOR
LIQUID FUEL, 50 GPM
TYPE II

BELVOIR RESEARCH, DEVELOPMENT AND ENGINEERING CENTER **MICROFILMED** 18 FEB 1992

CMPTR REQUEST NO 92HE3010
PCN D3BMEFD0848
ECP NUMBER 92HE301000
ECP DATE 14 NOV 91
CMPTR RUN DATE 01/29/92
PAGE 1 of 2

PARTS LIST FOR	REV	DOC DATE	DOC SYM	R SC	CAGE
PL13217E7140 FILTER/SEPARATOR	M	30 DEC 91		U 0	97403

DISTRIBUTION STATEMENT A. APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED."

FIND NO	CAGE	PART OR IDENTIFYING NO OR SPECIFICATION NO	GFP OPT	QTY	NAME/ DESCRIPTION OR NOTE	DOC SYM	R	SC
	97403	D13217E7140		REF	FILTER/SEPARATOR			
0001	97403	D13217E6311		001	TANK FILTER/SEPARATOR 50 GPM		U	U
0002	97403	B13217E6312		001	COVER TANK		U	U
0003	97403	C13216E2798		001	VALVE PRESSURE VENT MANUAL		U	U
0004	97403	B13216E2766		001	PLATE INSTRUCTION	C	U	U
0005	97403	C13217E6308		001	PLATE IDENT		U	U
0007	97403	C13217E5338		001	PLATE WARNING		U	U
0008	97403	B13219E9751		001	PLATE INSTRUCTION		U	U
0009	97403	D13219E9749-1		001	GAGE DIFFERENTIAL PRESSURE 1201 PG 2-2 W/.288-.290 DIA MTG HOLES	C	U	U
0010	96906	MS20822-5D		002	ELBOW FLARED TUBE AND PIPE THREADS, 90 DEGREE 5/16 TUBING OD 1/8 ANPT X .500-20 UNJF-3A AL ALY			U
0011	97403	C13217E5365-1		001	TUBE ASSEMBLY DIFFERENTIAL PRESSURE GAGE		U	U
0012	96906	MS20822-5-4D		002	ELBOW FLARED TUBE AND PIPE THREADS, 90 DEGREE 5/16 TUBING OD 1/4 ANPT X .500-20 UNJF-3A AL ALY			U
0013	97403	B13217E5360		001	GAGE SIGHT WATER LEVEL ASSEMBLY		U	U
0014	97403	B13216E2768		001	PLATE INSTRUCTION		U	U
0015	81349	MIL-H-13444		001	HOSE AND HOSE ASSY TY 2 3/8 NOM ID X 36 PLUS OR MINUS .5 L			U
0016	81348	WW-C-440		001	CLAMP TY E 5/8 NOM SZ			U
0017	97403	B13217E6309		001	COCK DRAIN HOSE BIB		U	U
0018	97403	C13218E0114-15		001	ELBOW PIPE STREET	A	U	U
0019	97403	B13216E2767		001	PLATE INSTRUCTION	M	U	U
0020	81349	MIL-F-52308	GFP	004	FILTER ELEMENT NSN 4330-00-983-0998		U	U
0021	97403	D13217E6316		004	CANISTER	C	U	U
0022	97403	D13217E6313		002	COUPLING HALF CLAMP PIPE		U	U
0023	97403	C13217E6318		001	BASKET COUPLING	C	U	U
0024	80204	ANS-B18.5		0002	ROUND HEAD BOLT SQUARE NECK .625-11 UNC-2A X 3.00 L CRES			U
0025	96906	MS15795-820		0002	WASHER FLAT-METAL, ROUND GENERAL PURPOSE .656 ID X 1.312 OD X .075 THKNS CRES PSVT			U
0026	96906	MS51971-7		0002	NUT PLAIN, HEXAGON-STEEL, CORROSION RESISTING, 300 SERIES, PASSIVATED, UNC-2B 5/8-11			U
0027	97403	C13217E6317		001	RETAINER CANISTER		U	U
0028	96906	MS35338-144		001	WASHER LOCK-SPRING, HELICAL, REGULAR (MEDIUM) SERIES 9/16 NOM SIZE CRES 300 SERIES PSVT			U
0029	97403	B13217E6315		001	ROD RETAINER		U	U
0030	81348	FF-N-845		001	NUT			U

A A

BELVOIR RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

CMPTR REQUEST NO 92HE3010
PCN D3SMEFD0840
ECP NUMBER 92HE301000
ECP DATE 14 NOV 91
CMPTR RUN DATE 01/29/92
PAGE 2

PARTS LIST FOR	REV	DOC DATE	DOC SYM	R SC	CAGE
PL13217E7140 FILTER/SEPARATOR	M	30 DEC 91		U U	97403

FIND NO	CAGE	PART OR IDENTIFYING NO OR SPECIFICATION NO	OFF OPT	QTY	NAME/ DESCRIPTION OR NOTE	DOC SYM	R	SC
					STY 1 TY A 1/2-13 UNC-2B AL ALY			
0031	96906	MS16203-29		0001	NUT			
					PLAIN, HEXAGON, AND HEXAGON JAM, UNC-2B, NONMAGNETIC			U
					1/2 NOM SZ X .448 MAX THKNS HEX COP-SILICON ALY			
0032	81349	MIL-S-7916		AR	SEALING COMPOUND			
0033	81349	MIL-S-8660		AR	SILICONE COMPOUND			U
0034	97403	C13217E5365-7		001	TUBE ASSEMBLY DIFFERENTIAL PRESSURE GAGE			U
0035	96906	MS51957-85		0002	SCREW		U	U
					MACHINE-PAN HEAD, CROSS-RECESSED, CORROSION-RESISTING			U
					STEEL, UNC-2A			
					.2500-20 X 1.500 L PSVT			
0036	96906	MS35338-139		0002	WASHER			
					LOCK-SPRING, HELICAL, REGULAR (MEDIUM) SERIES			U
					1/4 NOM SIZE CRES 300 SERIES PSVT			
0037	81352	AN960C416L		0002	WASHER			
					FLAT			U
					.265 ID X .500 OD X .032 THK CRES PSVT			
0038	97403	C13216E2789-4		001	CLAMP BAND	C	U	U
					820-36 & UA05-1612			
0039	81348	MMM-A-1617		AR	ADHESIVE			
					RUBBER BASE GENERAL PURPOSE TY III			U
0040	97403	C13220E9406-3		001	ADAPTER FOR WATER DETECTOR KIT		U	U
0041	81349	MIL-T-22361		AR	THREAD COMPOUND			U
					ANTISEIZE ZINC DUST-PETROLATUM			

SYMBOLS IN COLUMN DOC SYM
A=ALTERED ITEM DWG   I=GAGE DATA ON DWG   S=SOURCE CONT DWG
C=SPEC CONTROL DWG   L=SELL ITEM DWG   W=MOD WORK ORDER
E=INSP EQPT DWG   M=MULTI-USE DWG
F=INTFC CONT DWG   Q=SQAP DATA ON DWG

SYMBOLS IN COLUMN R (RIGHTS)
L=LIMITED RIGHTS   U=UNLIMITED RIGHTS
SYMBOLS IN COLUMN SC (SECURITY CLASSIFICATION)
C=CONFIDENTIAL   S=SECRET
U=UNCLASSIFIED   T=TOP SECRET

\#   INDICATES DATA NOT AVAILABLE
@   INDICATES THE REQUIRED DATA APPEARS ON THE NEXT LINE THAT BEGINS WITH THE SYMBOL @
DEF   INDICATES INSUFFICIENT INFORMATION WITHIN COMPUTER FILE TO COMPLETE REQUIRED DATA

PAGE 2 OF 2

The following pages are applicable to the VFM Fuel Pump (Ref. Section Four, paragraph 4.3.1.1):

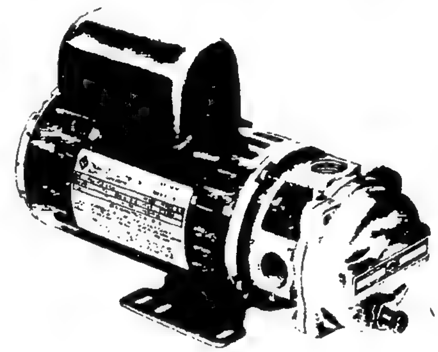
SERIES CR

E-36-13

burks pumps®

P.O. Box 431 Decatur, IL 62525-0431
Phone: 217/429-2591

Close Coupled Turbine Pump



APPLICATIONS

- Carpet Cleaning Machines
- Small Steam Generators
- Solar Heating Systems
- Booster Pump
- Injector Venturi Operation
- Cleaning and Flushing
- Low Flow Circulating
- Spray Nozzles
- Liquid Transfer
- Coolant Pump
- Aeration

BURKS exclusive, unique regenerative type turbine pumps are designed to handle clear water and many other nonabrasive, lower viscosity liquids on high pressure/low capacity applications with the greatest possible efficiency.

FEATURES

- Compact Size-Ideal for OEM Applications
- All Bronze Construction with Monel Impeller Blades
- Carbon/Ceramic Shaft Seal for Temperatures to 225°F
- #316 Stainless Steel Shaft
- Close Coupled Design — No Couplings or Alignment Problems
- Capacitor Start Motors Have Built-In Automatic Overload Protection
- Furnished with UL Approved Motor Lead
- Field Adjustable Impeller for Extended Service Life
- Easy to Service
- Every Pump Factory Tested

60 HZ **PERFORMANCE** **3450 RPM**

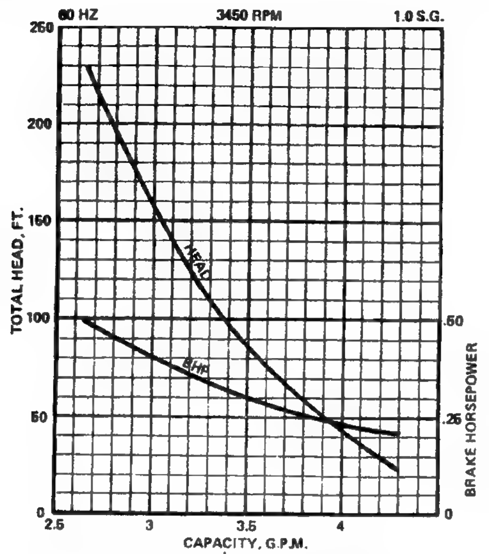
Catalog Number		H.P.	PSI / Feet	TOTAL HEAD								
				10.8 / 25	21.6 / 50	32.5 / 75	43.3 / 100	54.1 / 125	64.9 / 150	75.8 / 175	86.6 / 200	97.4 / 225
115V	230V			CAPACITY IN G.P.M.								
A3CR6M	3CR6M	1/3		4.3	3.9	3.6	3.4	3.2	3.0	2.9	2.8	2.7

Motors have ball/ball bearing construction and open ventilated enclosure. Motors are NOT drip-proof. Rated for continuous duty operation at all ratings shown. 60/50 HZ — 3500/2900 RPM
Maximum Inlet Pressure — 50 PSI
Maximum Working Pressure — 150 PSI

82

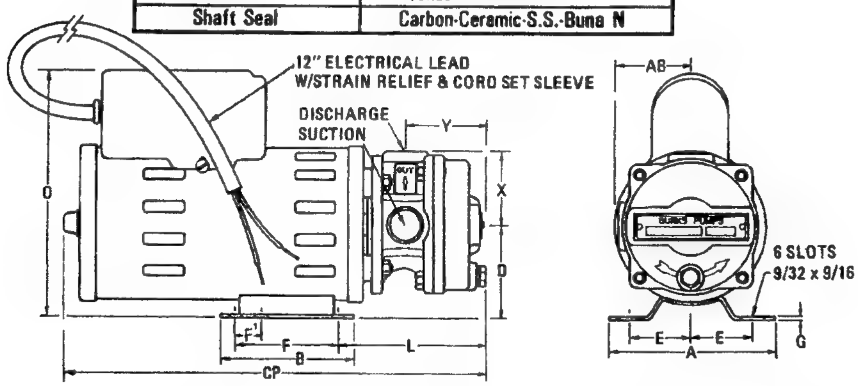
2860 A-13

Performance & Specifications



MATERIALS OF CONSTRUCTION

Part	Standard
Frame/Raceway	Bronze
Impeller	Bronze (Monel Blades)
Shaft	#316 Stainless Steel
Front Cover	Bronze
Shaft Seal	Carbon-Ceramic-S.S.-Buna N



DIMENSIONS

Tappings		Motor Frame	A	AB	B	*CP	D	E	F	F1	G	L	*O	X	Y
Suct.	Disch.														
½"	½"	36	4"	1⅞"	3¼"	10½"	2¼"	1½"	2½"	⅝"	1/16"	3⅝"	6¼"	1¾"	2"

*Approximate maximum dimension

A strainer, approximately 20 mesh, should be installed on the suction side of the pump to prevent chips, scale or hard foreign particles from entering the pump and damaging the raceway and impeller.

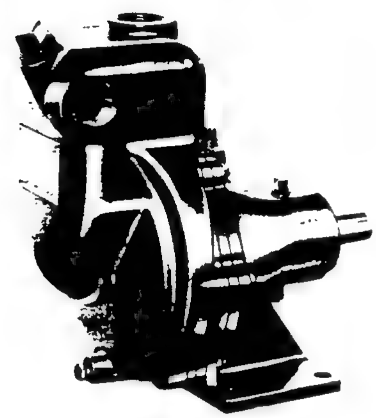
The following pages are applicable to the FTM Fuel Pump and Motor (Ref. Section Four, paragraph 4.4.1.1):

Self Priming Centrifugal

Basic Pump

Model 31A

Size 1" x 1"

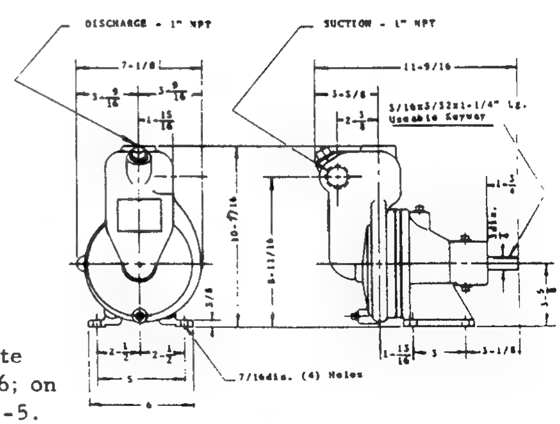


PUMP SPECIFICATIONS

Size: 1" x 1", NPT, female
Volute: Gray iron 30
(Max. hydrostatic test pressure 125 lbs., max. operating pressure 118 lbs.)
Impeller, closed type: Gray iron 25
(Handles $\frac{1}{4}$" spherical solids)
Wear ring: Stainless steel 304
Pedestal: Gray iron 30
Impeller shaft: Stainless steel 304
Seal plate: Gray iron 30
Seal: Mechanical self lubricated. Ceramic stationary seat. Carbon rotating face. Bellows is viton. Cage and spring are stainless steel. (Max. liquid temp. 212°F)

NOTE: Volute, impeller and seal plate on model 31A11-B are aluminum 356-T6; on model 31A12-B they are bronze 85-5-5-5. All other parts are the same on all models.

OUTLINE DRAWING (BASIC)

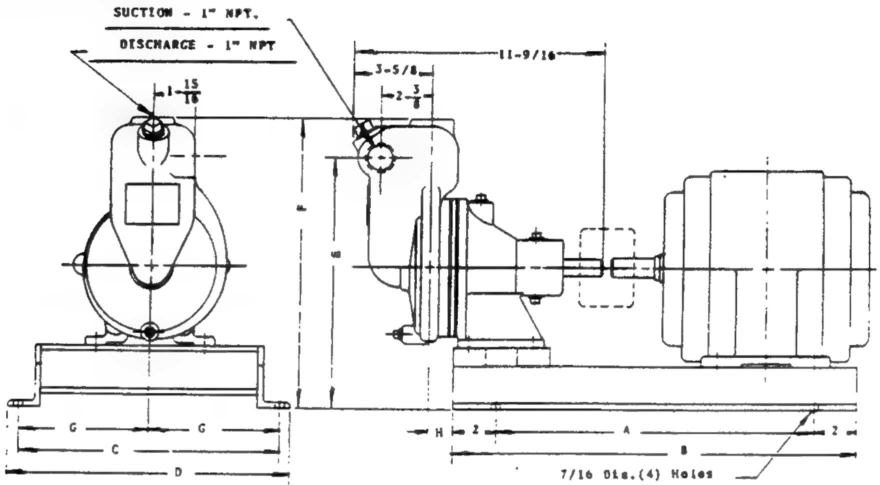


THE GORMAN-RUPP COMPANY . . . MANSFIELD, OHIO
GORMAN-RUPP OF CANADA LIMITED. ST. THOMAS. ONTARIO

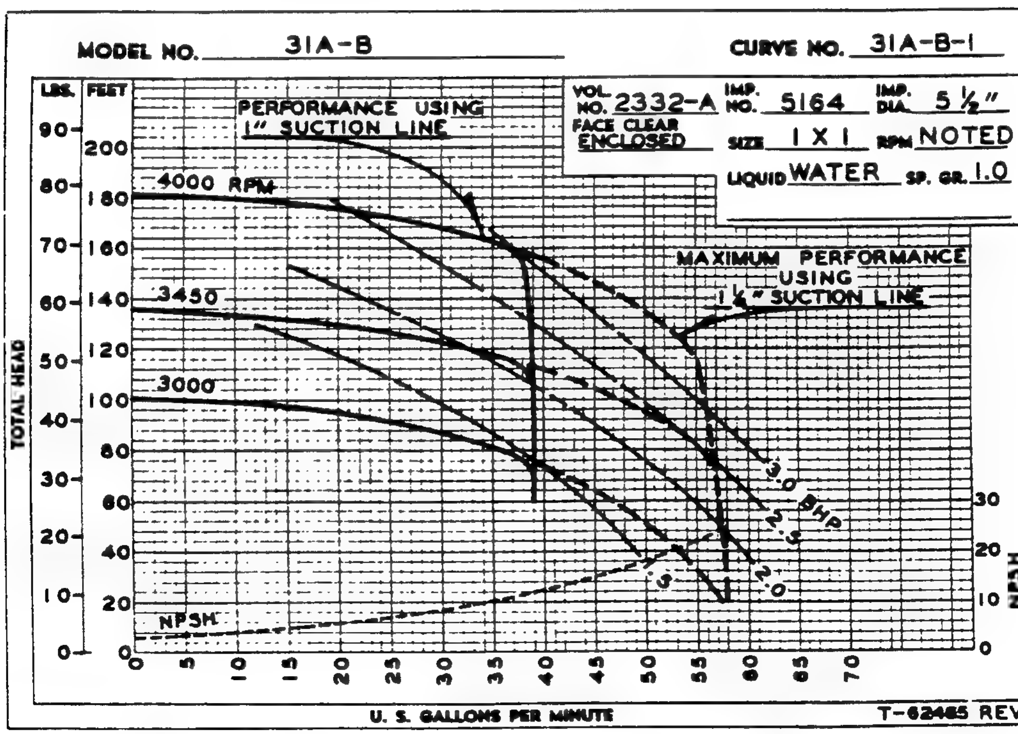
SPECIFICATION DATA

OVERALL DIMENSIONS and WEIGHTS APPROXIMATE

Net weight 28 lbs., shipping weight 33 lbs.



Frame	A	B	C	D	E	F	G	H	Base
56	12	16	9	10	10-1/4	12	4-1/2	1-1/16	10100
182&184	14-3/4	18-3/4	12	13	11-9/16	13-5/16	6	1-1/16	10600
213&215	18-1/4	22-1/4	12-3/4	13-13/16	13-5/16	15-1/16	6-3/8	13/16	10965



THE GORMAN-RUPP COMPANY . . . MANSFIELD, OHIO

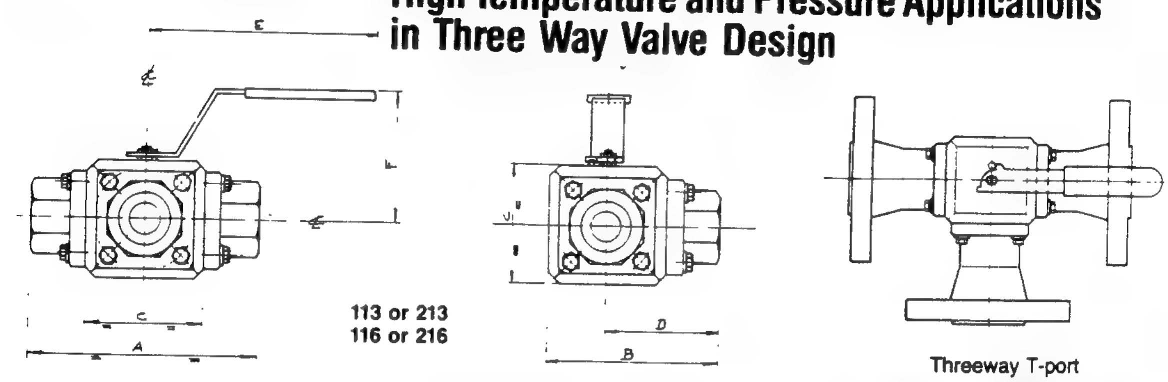
GORMAN-RUPP OF CANADA LIMITED. ST. THOMAS. ONTARIO   Printed in U. S. A.

The following pages are applicable to: Ref. Section Four, paragraphs 4.2.4.2 (Valve V10), 4.2.4.5 (Valve V1), 4.3.3.3 (Valve V8), 4.3.3.4 (Valve V9), 4.4.3.2 (Valve V4), 4.4.3.3 (Valve V5) and 4.4.3.4 (Valve V13):

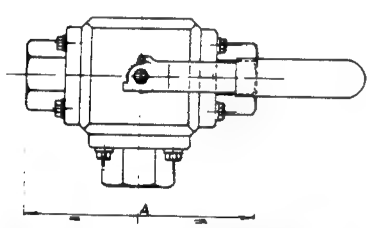
SUPER STAR

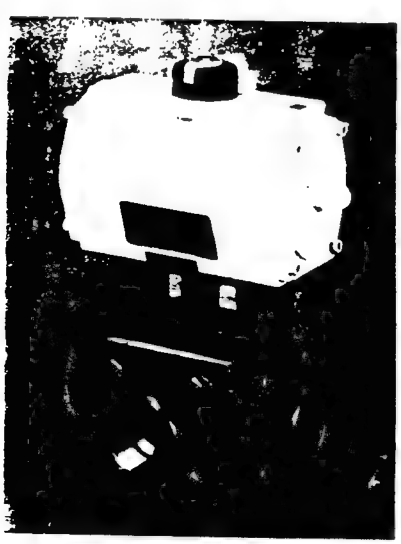
Three Way Ball Valve

High Temperature and Pressure Applications in Three Way Valve Design



113 or 213
116 or 216





Designations:
Full Port Stainless – Figure Number 116
Full Port Carbon – Figure Number 113
Standard Port Stainless – Figure Number 216
Standard Port Carbon – Figure Number 213

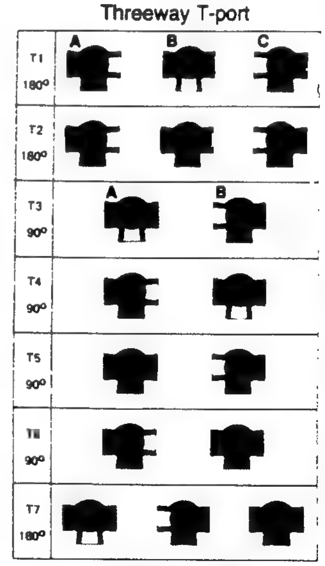
1. Multiport ball valve designed for higher operating pressures.
2. Each port is provided with metal encapsulated seats for higher temperature capability.
3. A rugged constructed valve with metal seat housing designed for pulsating pressures.
4. Wide choice of seat materials for specific or special service applications.
5. Precision machined for control accuracy and outstanding service life.
6. A multiport ball valve designed for automation.
7. Bolted covers are available with threaded, socket weld, butt weld or flanged ends.
8. Bolted covers allow easy removal of the valve body from the system at all three connection points.

Dimension for Ball Valves
* Type Super Star 3 Way T or L Port.

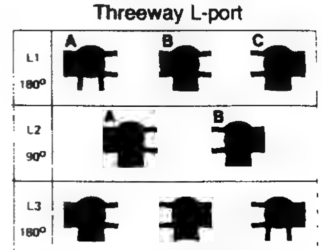
F.B.	R.B.	'A'	'B'	'C'	'D'	'E'	'F'
¼-⅜"	½	4.37	3.27	2.17	2.19	5.98	2.75
½"	¾"	4.69	3.52	2.38	2.34	7.00	3.15
¾"	1"	5.91	4.48	3.07	2.95	7.00	3.82
1"	1¼"	6.22	4.78	3.35	3.11	8.86	4.25
1¼"	1½"	6.65	5.36	3.86	3.43	8.86	4.45
1½"	2"	7.76	6.00	4.25	3.88	8.86	4.85

• AVAILABLE IN Standard port thru 3"
Full port thru 2½"

Threeway T-port



Threeway L-port

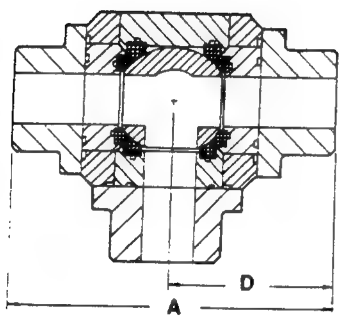


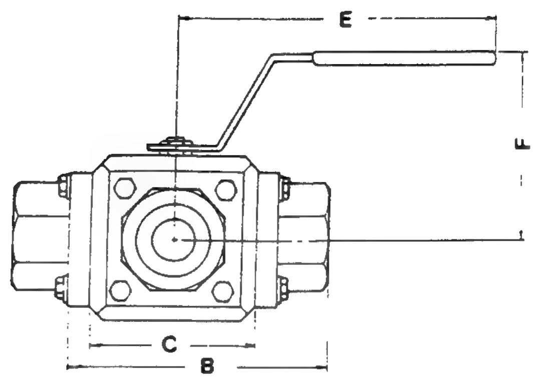
MARWIN
CINCINNATI
7127 Longview Street
Cincinnati, Ohio 45216
Telephone (513) 821-0724
Fax (513) 821-0740

THREE WAY BALL VALVE

Designed for Higher Operating Pressures and Temperature Applications

SIZES: ¼ - 2½ (Full Port); ½ - 3 (Red. Port)





Available in T-port (3BT) or L-port (3BL) Design.

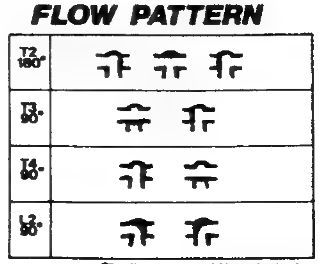
NOTES

PART NAME	A105/F316 MATERIAL	F316/F316 MATERIAL
Handle	C.S. Galvanized	C.S. Galvanized
Handle Nut	C.S. Cadmium plated	A194-B8
Packing	Graphoil	Graphoil
Spring Washer	S.S. Special Spring Steel	S.S. Special Spring Steel
Stem	ASTM A182 F316	ASTM A182 F316
Gland Packing	ASTM A182 F316L	ASTM A182 F316L
Thrust Washer	PTFE	PTFE
Stem O-Ring	Viton	Viton
Ball	ASTM A182 F316	ASTM A182 F316
Seats	Starfill	RPTFE
First Body Gasket	RPTFE	Graphoil
Body	A105	A182 F316
End Connection	A105	A182 F316L
Stop Pin	C.S.	S.S.
Anti St. Device	S.S. ASTM A182 F316	S.S. ASTM A182 F316
Bolts	A193-B7	A193-B8
Stop Washer	S.S. ASTM A182 F316	S.S. ASTM A182 F316
Retainer Seal	RPTFE	RPTFE
Seat Retainer	A105	A182 F316

DIMENSIONS

SIZE Full	SIZE Red.	A	B	C	D	E	F	Wgt. (Lbs.)	Torq. in-lbs
¼ & ⅜	½	4.37	3.85	2.17	2.19	5.96	2.75	5	
½	¾	4.69	4.20	2.36	2.34	7.60	3.15	6	
¾	1	5.91	5.07	3.07	2.95	7.60	3.62	11	
1	1¼	6.22	5.43	3.35	3.11	8.86	4.25	15	
1¼	1½	6.66	6.10	3.86	3.43	8.86	4.45	22	
1½	2	7.76	8.50	4.25	3.88	8.86	4.65	27	
2	2½	10.30	9.05	6.45	5.15	13.70	5.30	82	
2½	3	17.20	13.02	7.30	8.60	13.70	6.50	105	

FLOW PATTERN



Other flow patterns available upon request

MARWIN
CINCINNATI

The following pages are applicable to: Ref. Section Four, paragraphs 4.2.4.4 (Valve V12), 4.3.2.2 (Valve V14) and 4.4.2.2 (Valve V15):

SERIES "TB" THRIFT-BALL" WAFER-STYLE VALVES

1/2" TO 12" 150# TO 1500# ANSI -427°F TO +500°F

FEATURES:

This compact, economical ball valve, which features a blow-out proof stem exceeds the strict ruggedness and dependability requirements of many process industries. Its simple design can be constructed from a wide variety of materials thereby offering an unlimited array of service applications. Available in cryogenic configurations. 316 SST Body and Trim, Teflon seats and seals.

CONNECTIONS: RF or RTJ end

APPLICATIONS Petro-chemical fluids oil refinery products abrasive and corrosive media water-oil-gas service helium cryogenic hydrogen and nitrogen

SERIES "MB" MINI-BALL VALVES

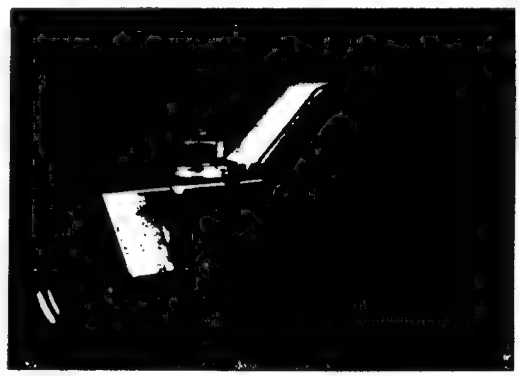
1/4 TO 2 TO 4500 PSI -427°F TO +600°F

FEATURES:

This rugged, versatile, one-piece ball valve constructed from bar stock, provides positive shut-off at high pressures. It features a pressure energized stem seal and blow-out proof stem. Options include an extended stem for cryogenic applications. 316 SST Body and Trim, Teflon or Kel-F seats, and Teflon seals.

CONNECTIONS: NPT (F) or MS 33649

APPLICATIONS: Designed to handle a variety of corrosive and non-corrosive fluids.



In addition to the valves described in this brochure, Hi-Gear has compiled a vast library of specialized designs during 30 years of designing and manufacturing valves. If your application requires a unique valve, chances are Hi-Gear engineers have already solved a similar problem. Some examples of valve and material options are listed below.

ADDITIONAL MATERIALS OF CONSTRUCTION:

Body & Trim:....................Monel, Alloy 20, Hastelloy, Nickel
Seats:....................PEEK, Kel-F, Vespel
Filled TFE, UHMW Polyethylene
Seals:....................Viton, Chemraz, Kel-F, PEEK, Teflon

OPERATORS:

In most cases, our valves can be operated either manually or with an electric or pneumatic actuator.

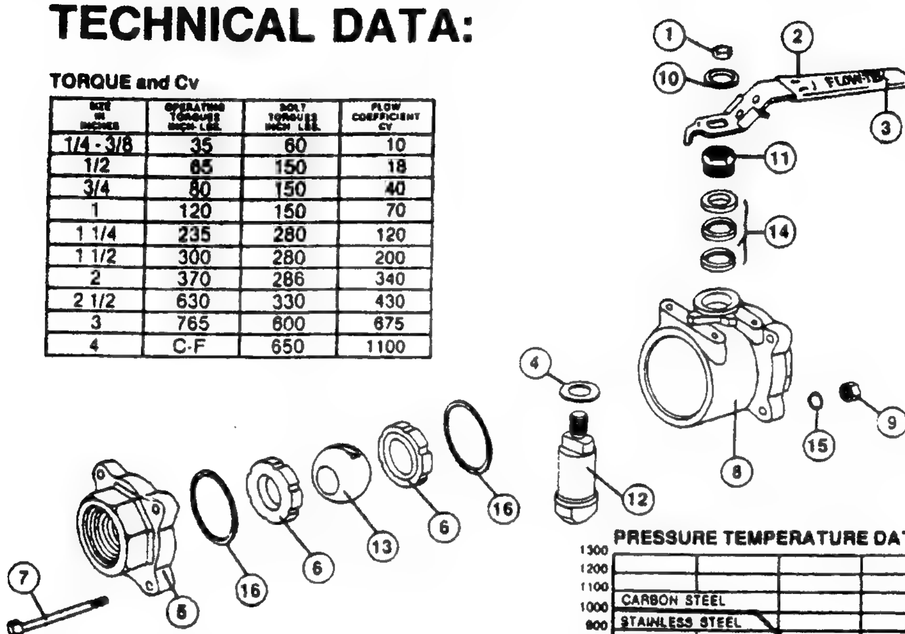
For information and pricing contact Hi-Gear's sales engineers at:

Hi-Gear, Inc., 4131 Northgate Blvd., Sacramento, CA 95834 - (916) 567-1125/FAX (916) 567-1127
Division of U.S. Paraplate Corporation

TECHNICAL DATA:

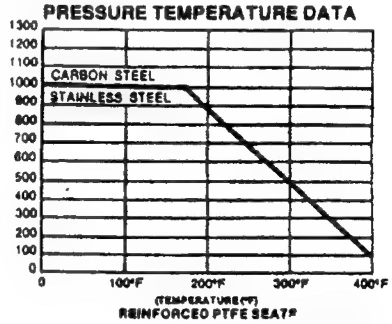
TORQUE and Cv

SIZE IN INCHES	OPERATING TORQUES INCH LBS.	BOLT TORQUES INCH LBS.	FLOW COEFFICIENT CV
1/4 - 3/8	35	60	10
1/2	65	150	18
3/4	80	150	40
1	120	150	70
1 1/4	235	280	120
1 1/2	300	280	200
2	370	286	340
2 1/2	630	330	430
3	765	600	675
4	C-F	650	1100



FLOW-TEK's improved 2 pc. seat design offers a separate seat and body seal, numbers 6 and 16.

PRESSURE TEMPERATURE DATA

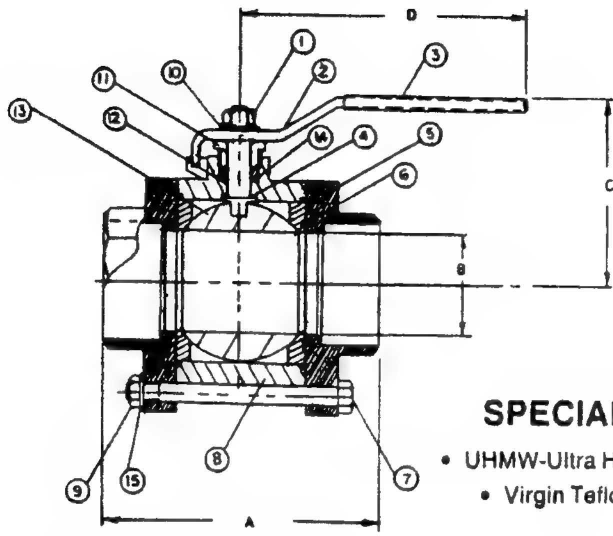


DIMENSIONS

WEIGHTS

SIZE IN INCHES	TH'D-ENDS SS	A	B	C	D	UNIT WT. IN LBS.	BOX QTY.
1/4	7101	2 1/2	7/16	2 1/8	3 3/4	1.0	52
3/8	7102	2 1/2	1/2	2 1/8	3 3/4	1.0	52
1/2	7103	2 3/4	5/8	2 1/2	4 7/8	1.5	40
3/4	7104	3 1/4	13/16	2 3/4	5 3/8	2.15	32
1	7105	3 3/4	1	3	5 3/4	3.0	18
1 1/4	7106	4 7/16	1 1/4	3 1/8	6 3/4	4.75	12
1 1/2	7107	4 7/8	1 1/2	4	8	6.7	8
2	7108	5 11/16	2	3 3/4	8	10.5	5
2 1/2	7109	6 3/4	2 1/2	5 1/2	10	20.0	2
3	7110	7	3	5 1/2	11 1/4	32.0	1
4	7111	8 1/2	3 7/8	6 1/2	12	48.0	1

A = FF ± 1/16"
6, 8 and 10 inch available - CF for dimensional information



FLOW-TEK

All valves 100% air tested, under water, at 100 P.S.I. open and closed positions

SPECIAL SEAT MATERIALS

- UHMW-Ultra High Molecular Weight Polyethylene
- Virgin Teflon
- Carbon Filled Teflon

BILL OF MATERIALS

ITEM NO.	PART NAME	STAINLESS STEEL 7000 SERIES	CARBON STEEL 8000 SERIES	QTY.
1	LEVER NUT	ASTM A492 TYPE 304	CARBON STEEL	1
2	LEVER	ASTM A167 TYPE 304	CARBON STEEL	1
3	LEVER SLEEVE	VINYL PLASTISOL	VINYL PLASTISOL	1
4	THRUST WASHER	PTFE	PTFE 15% GLASS FIBER	1
5	END CONNECTOR	ASTM A351 Gr. CF8M	ASTM A126 Gr. WCB	2
6	SEATS	PTFE 15% GLASS FIBER	PTFE 15% GLASS FIBER	2
7	HEX BOLTS	ASTM A492 TYPE 304	SAE 4135/4140	4
8	BODY	ASTM A351 Gr. CF8M	ASTM A216	1
9	NUTS	ASTM A492 TYPE 304	CARBON STEEL	4
10	WASHER	ASTM A167 TYPE 304	CARBON STEEL	1
11	PACKING GLAND	ASTM A276 TYPE 316	CARBON STEEL	1
12	STEM	ASTM A276 TYPE 316	ASTM A276 TYPE 316	1
13	BALL	ASTM A276 TYPE 316	ASTM A276 TYPE 316	1
14	V-RING STEM PACKING	PTFE 20% GLASS FIBER, 5% GRAPHITE	PTFE 20% GLASS FIBER	1
15	SPRING WASHER	ASTM A492 TYPE 304	SAE J429	4
16	BODY SEAL	PTFE 15% GLASS FIBER	PTFE 15% GLASS FIBER	2

High performance V-Ring packing is standard on all valves.

MODEL NUMBERS

THREADED END	Series 7100 FT
SOCKET WELD	Series 7200 FT
BUTT WELD END	Series 7300 FT
150 LBS. FLANGE	Series 7400 FT
QUICK CLAMP	Series 7500 FT
CAM LOCK	Series 7600 FT.

ORDERING INFORMATION:

All Model series numbers are coded

ie: Series 7108 STAINLESS STEEL
or Series 8204 CARBON STEEL

SIZE
TYPE OF END
BODY MATERIAL

Technical data

VALVCON V & ADC- SERIES ELECTRIC VALVE ACTUATORS

- Voltage–*24, 115 or 230 VAC (50/60 Hz); 12 or 24 VDC.*
- Torque–*150, 300, 600, 1000, 1500, 2000, 2500, 3000 in./lbs.*
- Enclosure– *Epoxy Coated Cast Aluminum*
- Duty Cycle–*Standard (25%) – Extended (75%) – ADC (100%)*
- Bolt Pattern– *ISO Standard (5211)*

"MOTHER/ DAUGHTER" BOARDS

A master PC (or "mother") board connected to the wiring strip in Valvcon actuators accepts plug-in modular (or "daughter") boards for a variety of accessory functions. The solid-state electronics provide convenient field installation as well as precise control.

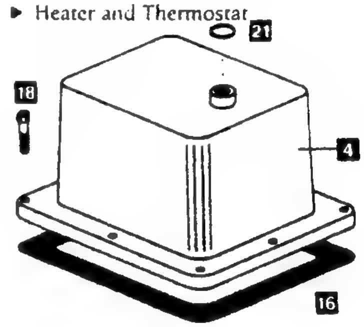
ACCESSORIES

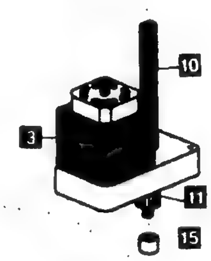
V-Series Accessories

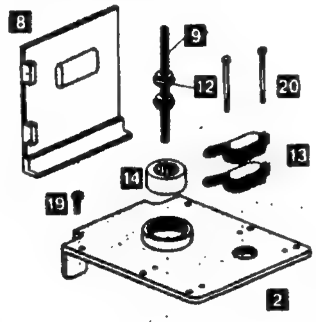
- 1/4-turn Modulating Control† – *4-20 mA, 0-1000 ohm (and others)*
- Cycle Rate Regulator†
- Timer† – *for timed operation*
- Relay Board† *(2 or 3 wire control)*
- Center-off† – *for 180° operation*
- Mechanical Brake
- Heater and Thermostat

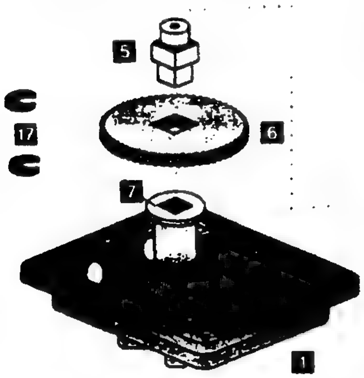
ADC-Series Accessories

- ADC Fail-safe Electric
- ADC Fail-safe w/Control Pkg.
- ADC Torque Switch
- ADC Multi-Turn
- Heater and Thermostat









(Internal gearing shown for smaller model only.)

1 Die-cast Aluminum Base
2 Motor Support Plate
3 Motor Gearbox with hardened steel gears
4 Die-cast Aluminum Cover
5 Output Shaft
6 Hardened Steel Bull Gear
7 Output Coupling with Bushing
8 Mother Board with Capacitor
9 CAM Shaft
10 Override Shaft
11 Hardened Steel Motor Pinion Gear
12 CAM(s)
13 Limit Switch
14 Motor Support Plate Needle Bearing
15 Motor Pinion Needle Bearing
16 Gasket (Weatherproof Only)
17 Bull Gear Retaining Ring
18 Hex Screw
19 Motor Support Plate Screw
20 Limit Switch Screw
21 O-ring

† Daughter Board

V-SERIES

ACTUATOR MODEL*	BREAKAWAY TORQUE	STANDARD DUTY CYCLE (S) CYCLE TIME	STANDARD DUTY CYCLE (S) VOLTAGE	STANDARD DUTY CYCLE (S) DUTY CYCLE	STANDARD DUTY CYCLE (S) AMP DRAW	EXTENDED DUTY CYCLE (E) CYCLE TIME	EXTENDED DUTY CYCLE (E) DUTY CYCLE	EXTENDED DUTY CYCLE (E) VOLTAGE	EXTENDED DUTY CYCLE (E) AMP DRAW	DC CYCLE TIME	DC DUTY CYCLE	DC VOLTAGE	DC AMP DRAW
SV150	150	5	115 VAC or 230 VAC or 24 VAC	25%	.6 @115 VAC .4 @230 VAC	10	75%	115 VAC or 230 VAC or 24 VAC	.3 @115 VAC .2 @230 VAC	5	100%	12 VDC or 24 VDC*	1.1
SV300	300	10				15				10			1.1
SV600	600	15				30				15			1.1
SV1000	1000	30				N/A			N/A	N/A			N/A
LV1000	1000	15			.8	15			.6	15			2.6
LV1500	1500	20			.8	20			.6	20			2.6
LV2000	2000	30			.8	30			.6	30			2.6
LV2500	2500	45			1.5	45			.6	35			2.6
LV3000	3000	45			1.5	45			.5	N/A			N/A

V-Series Options:
A-Timer; B-C R.R.(Cycle Rate Regulator); C-Modulating Control Pkg † (4-20mA, 0-1000ohm, and others, includes pot.); D-180° Center Off; G-4-20mA re-transmit, K-Mechanical Brake; O-Dual Conduits, P-Potentiometer; Q-Special; R-Relay Board, R2-Computer Interface Board; S-Additional Switches & Cams (*specify up to 3*); T-Heater and Thermostat

ADC-SERIES

ACTUATOR MODEL*	BREAKAWAY TORQUE	STANDARD DUTY CYCLE (S) CYCLE TIME	STANDARD DUTY CYCLE (S) VOLTAGE	STANDARD DUTY CYCLE (S) DUTY CYCLE	STANDARD DUTY CYCLE (S) AMP DRAW
SADC150	150	5	115 VAC or 230 VAC or 12 VDC or 24 VAC	100%	2
SADC300	300	10			2
SADC600	600	15			2
LADC1000	1000	15			4
LADC1500	1500	21			4
LADC2000	2000	29			4
LADC2500	2500	35			4

ADC-Series Options:
C-Modulating Control Pkg.† or CL2-Fail-safe with Modulating Control‡ (*4-20mA, 0-1000ohm, 0-10VDC includes pot.*); J-Torque switch; K-Brake; L2-Fail-safe‡; N-Multi-turn; P-Potentiometer; Q-Special; S-Additional switches & cams (*specify up to 2*); T-Heater and Thermostat

Use a filtered power supply for maximum life. Cycle times are approximate only. Current draw at maximum efficiency

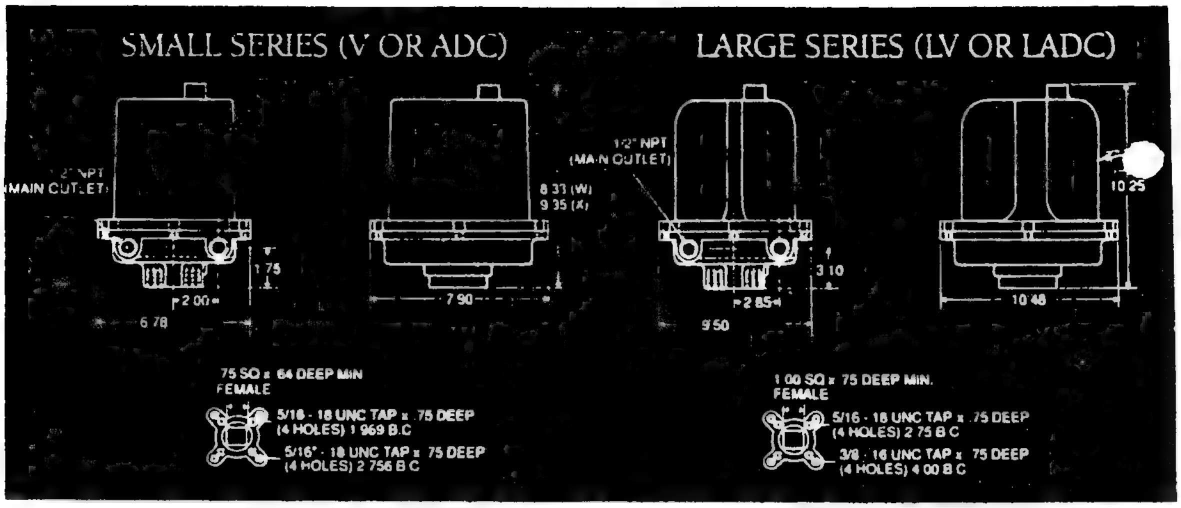
V-SERIES AND ADC-SERIES:

Enclosure^Δ: W-Designed for NEMA IV^Δ weatherproof requirements. X-Designed for NEMA VII° explosion proof requirements.
Temperature Limits (all models): -40°F (with heater & thermostat) to 150°F (max.).
Lubrication: Permanently lubricated gear train and bearings
Conduit Connection: 1-1/2" NPT (2-optional)
Operation: Reversing. Limit switches, cam operated. Adjustable from 0° to 300°.
Approximate Weight: 12.5 lbs. for smaller models (SV); 25 lbs. for larger models (LV).

**Actuator model must be amplified by full "How to order" specifications including enclosure. See examples below*
˙Amps rated at full running torque. Amp draws shown are for 115 VAC only. For 230 VAC, consult factory.
˙24 VDC Cycle time and amp draw are half of 12 VDC
†Specify analog signal
‡CL3 & L3 for LADC
ΔCSA Hazardous Location or Weatherproof certification available on selected models. Consult factory for details.
°NEMA VII Class I, Division I, Groups C and D, and Class I, Division II, Groups E, F and G.

HOW TO ORDER
VALVCON V- & ADC-SERIES ELECTRIC ACTUATORS

SERIES	ENCLOSURE	TORQUE	OPTIONS	DUTY CYCLE	POWER
SV	W	600	C	E	115VAC
LADC	X	1500	L3	S	115VAC

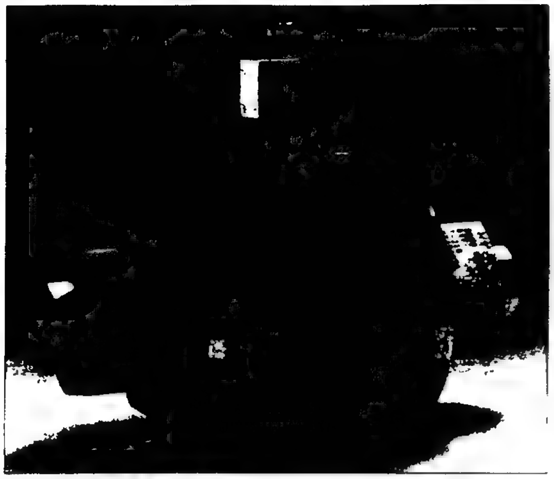


VALVCON CORPORATION
Mail To: P O Box 901
Milford, NH 03055
Ship To: Pine Valley Mill Building
Elm Street
Milford, NH 03055
Telephone: (603) 654-6111
Fax: (603) 654-9050

VALVCON
The future is in control

The following pages are applicable to: Ref. Section Four, paragraphs 4.2.4.3 (Valve V2) and 4.4.3.1 (Valve V3):

A sampling of Hi-Gear's Time-Proven, Reliable Valve Designs



SERIES "6000" HIGH CYCLE BALL VALVES

1/2" TO 4 — TO 6000 PSI — -20°F TO +300°F

FEATURES:
The ultimate in high-pressure ball valves designed for high cycle applications. This bi-directional, 3-piece valve features pressure energized, wear compensating seats for low maintenance and long service. Field convertible from manual to actuated while valve is under pressure. Materials of construction are: 316 SST body and trim, Vespel seats and Viton seals.

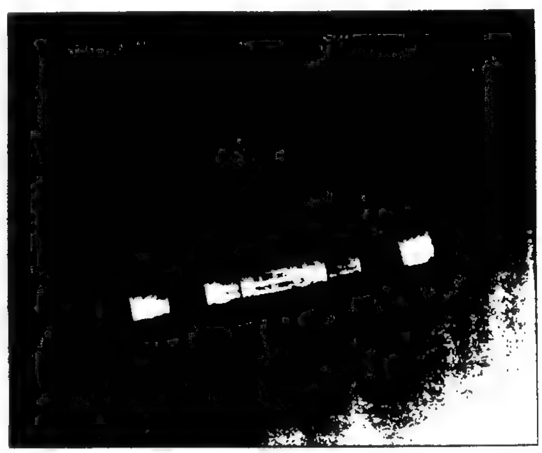
CONNECTIONS:	Socketweld union end (standard) Also available flanged buttweld screwed (tube or pipe)
APPLICATIONS:	High pressure oxygen inert gas and most hydraulic applications.

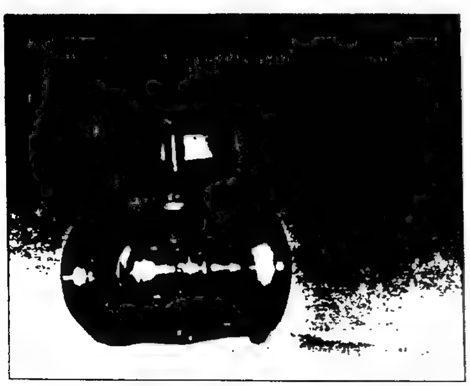
SERIES "HP" SEVERE SERVICE BALL VALVES

3/4" TO 8" — 600# TO 2500# ANSI — -65°F TO +500°F

FEATURES:
Our "HP" Series ball valves give outstanding performance in the most difficult process applications. For higher valve performance, this bi-directional trunnion mounted valve, compatible with most fluids, has a blow-out proof stem and bubble tight operation. It also features pressure energized, wear compensating seats. Materials include: 316 SST body and trim, Nylatron seats, and Teflon seals.

CONNECTIONS:	RF and RTJ Flange, Socket or Buttweld
APPLICATIONS:	Chemical and petro-chemical processing petroleum refining natural gas processing and most hydraulic systems.





SERIES "FW" FOUR WAY BALL VALVES

4" - 6" - 8" — 150# TO 600# ANSI — -65°F TO +180°F

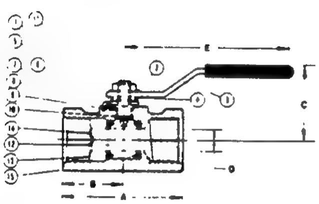
FEATURES:
Our four way ball valve is constructed to handle the most difficult gas or liquid process applications. Rugged stem and trunnion bearings, coupled with pressure energized seats, extend service life and reduce down-time. Materials include: 316 SST body and trim, Nylatron or Kel-F seats and Viton seals.

CONNECTIONS.	RF Flange per ANSI B16.5
APPLICATIONS.	Recirculation blending, diversion and mixing systems.

bronze ball valves

One Piece Body • Blowout-Proof Stem • Bronze Trim • Vented Ball
600 lb. WOG

Federal Specifications: WW-V-35, Type II, Class A, Style 3



T-560-BR Series
NPT x NPT

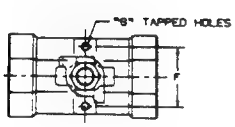
MATERIAL LIST

	PART	SPECIFICATION
1	Handle Nut	Zinc Plated Steel
2	Identification Plate	Aluminum
3	Handle	Zinc Dichromate Plated Steel Plastisol Coated
4	Packing Nut	Stainless Steel ASTM A-582 Type S416
5	Belleville Washer	Zinc Plated Steel
6	Travel Stop	Zinc Dichromate Plated Steel
7	Pack Gland	Brass ASTM B-16 Alloy 360
8	Packing	Reinforced TFE
9	Grounding Washer	Stainless Steel ASTM A-167 Type 304
10	Thrust Washer	Reinforced TFE
11	Stem	Bronze ASTM B-371 Alloy 694
12	Ball*	Bronze ASTM B-584 Alloy 844
13	Seat Ring (2)	TFE (Y), Reinforced TFE (R)
14	Body Insert	Bronze, ASTM B-584 Alloy 844
15	Body	Bronze, ASTM B-584 Alloy 844
16	Body Endpiece (Not Shown)	Brass ASTM B-16 Alloy 360 1/4 & 3/8 Size only

*Ball Material on 1/4" 3/8" 1/2" and 3/4" sizes is ASTM B-16 Alloy 360

T-560-BR-Y-20
threaded
TFE Seats and Seals
with Bronze trim

T-560-BR-R-20
threaded
Reinforced TFE Seats
and Seals
with Bronze trim



Note: Holes are only Tapped for Actuated Valves.

DIMENSIONS — WEIGHTS — QUANTITIES

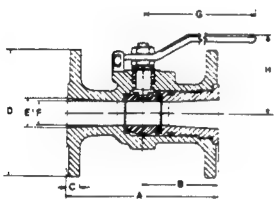
Size	A	B	C	D	E	F	G	Approx. Net Wt. Lb.	Master Carton Qty.
1/4	2 [illegible]	1 [illegible]	1 [illegible]	[illegible]	4	1 [illegible]	10-24	6	50
3/8	2 [illegible]	1 [illegible]	1 [illegible]	[illegible]	4	1 [illegible]	10-24	6	50
1/2	2 [illegible]	1 [illegible]	1 [illegible]	[illegible]	4	1 [illegible]	10-24	6	50
3/4	2 [illegible]	1 [illegible]	1 [illegible]	[illegible]	4	1 [illegible]	10-24	8	50
1	3 [illegible]	1 [illegible]	2	[illegible]	4 [illegible]	1 [illegible]	[illegible]-20	1.3	30
1 [illegible]	3 [illegible]	1 [illegible]	2 [illegible]	[illegible]	4 [illegible]	1 [illegible]	[illegible]-20	2.0	20
1 [illegible]	4	2 [illegible]	2 [illegible]	1	6 [illegible]	1 [illegible]	[illegible]-20	2.8	20
2	4 [illegible]	2 [illegible]	2 [illegible]	1 [illegible]	6 [illegible]	2 [illegible]	[illegible]-20	4.3	10

NOTE For specific pressure temperature relationships refer to page 16

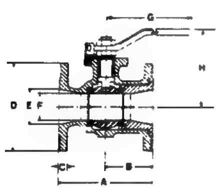
NIBCO

class 150 flanged ball valves

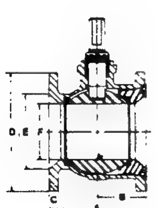
Conforms to ANSI B16.34, MSS-SP-72



F-510 Series
Configuration for ½" - 1"



F-510 Series
Configuration for 1½" - 8"



F-510 Series
Configuration for 10" - 12"

MATERIAL LIST

Part Name	Carbon Steel	Stainless Steel	Alloy 20	Monel
Body	A216 Type WCB	A351 GR CF8M	A351 GR CN7M	A-494-87A GR M35
End Plug**	A216 Type WCB	A351 GR CF8M	A351 GR CN7M	A-494-87A GR M35
Ball**	Carbon Steel Hard Chrome Plated	A351 GR CF8M	A351 GR CN7M	B164 GR N04400
Stem	Carbon Steel Hard Chrome Plated	A276 GR 316 SS	B473 GR N08020	B164 GR N04400
Seat	15% Glass Filled TFE			
Packing	V-Ring* TFE with Grounding Device			
Pack Gland	304 Stainless Steel		Monel B164 GR N04400	
Stop Plate	Stainless Steel			
Thrust Washer	15% Glass Filled TFE			
Gland Nut	Carbon Steel-Plated	300 Stainless Steel	Monel	
Handle Nut	Carbon Steel-Plated	300 Stainless Steel		
Wrench	Ductile Iron			
'O' Ring	Fluorocarbon			
Gasket	Spiral Wound Gasket			

* Graphite in API 607 firesafe design
** Cast specifications shown—smaller sizes may be made from equivalent bar stock specifications

F-510 Series
flanged

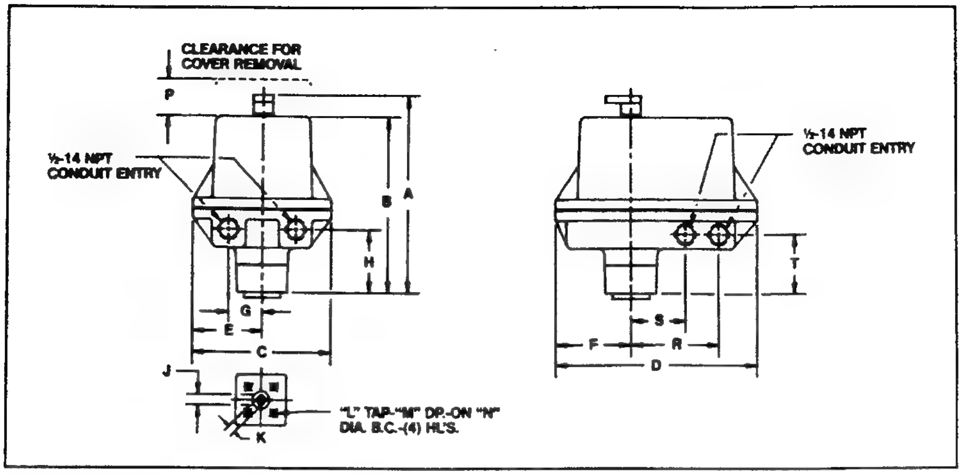
DIMENSIONS — WEIGHTS

Size	A	B	C	D	E	F	G	H	Wt.
½	4.25	2.12	.44	3.50	.50	.43	5.0	2.4	2.5
¾	4.62	2.31	.44	3.88	.75	.62	6.5	2.7	3.2
1	5.00	2.50	.44	4.25	1.00	.81	6.5	3.0	3.9
1½	6.50	3.25	.56	5.00	1.50	1.19	9.0	4.2	11.9
2	7.00	3.00	.62	6.00	2.00	1.50	9.0	4.3	16.9
3	8.00	4.00	.75	7.50	3.00	2.37	16.6	6.2	40
4	9.00	4.25	.94	9.00	4.00	3.00	16.6	7.2	62
6	10.50	5.25	1.00	11.00	6.00	4.37	32.8	10.1	118
8	11.50	5.50	1.12	13.50	8.00	5.94	32.8*	10.1*	192
10	13.00	6.50	1.19	16.00	10.00	7.50	8.88*	15.00*	290
12	14.00	7.00	1.25	19.00	12.00	9.50	10.78*	16.90*	433

* Handles not recommended for valves 8" and up.
Use of actuators is recommended

See Page 3
For Specific
Trim Combinations

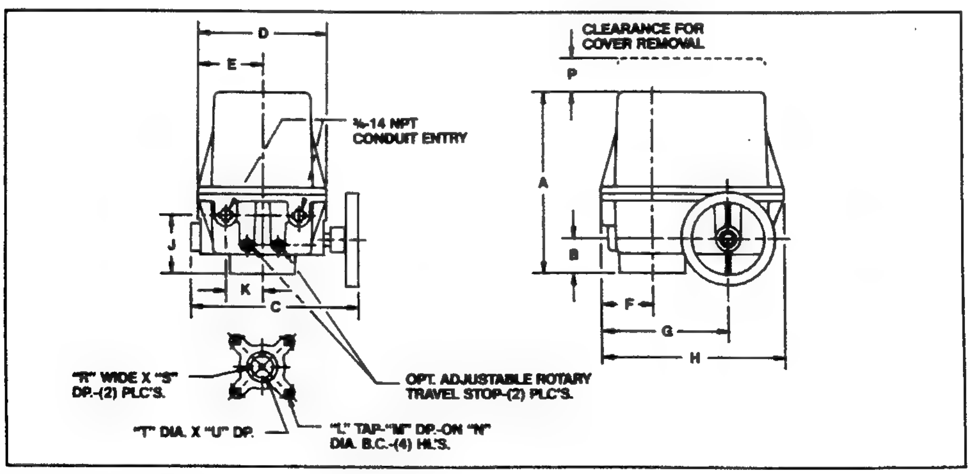
NIBCO INC., ELKHART, INDIANA



Dimensions

Dimensions (inches) — inches
Mounting dimensions (mm) — mm

DESC.	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T
[illegible]	8.18	7.36	6.25	8.25	3.12	3.12	1.25	2.73	0.476 / 12.1 mm	0.354 / 9 mm	M5	10 mm	1.417 / 36 mm	5.00			
[illegible]	10.59	8.97	7.75	9.75	3.88	3.88			0.712 / 18.1 mm	0.551 / 14 mm	M6	10 mm	1.968 / 50 mm	8.00	4.13	2.50	3.41



Dimensions

Dimensions (inches) — inches
Mounting dimensions (mm) — mm

DESC.	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U
[illegible]	14.00	2.69	12.94	10.00	5.00	3.88	9.69	14.00	4.50	2.75	½-13	0.88	5.00	8.00	0.254 / 6 mm	1.25	1.760 / 45 mm	1.44

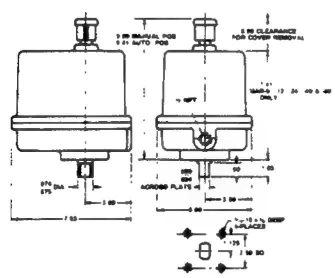
NIBCO

ball valve actuation information

Electric Actuators

MODELS

Without Manual Override	With Manual Override
MAR-9	MAR-10
MAR-24	MAR-25
MAR-49	MAR-50
MAR-89	MAR-90



TORQUE RATINGS
(at 60Hz) in seconds/90° turn and torque in pound inches

Model	0.33 Sec	2 Sec	5 Sec	10 Sec	15 Sec	30 Sec	60 Sec
MAR-9 & -10	—	120	—	275	—	300	400
MAR-24 & -25	—	—	—	400	—	500	600
MAR-49 & -50	—	600	—	600	—	700	700
MAR-89 & -90	—	—	1000	—	1000	—	—

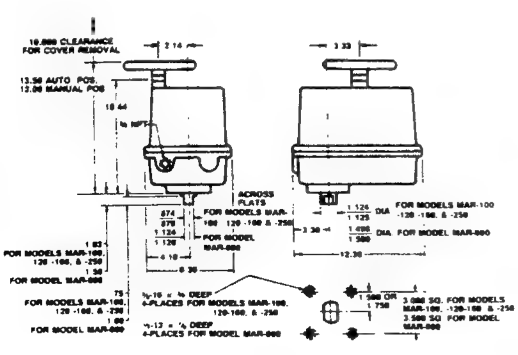
CURRENT RATINGS
in amps, at standard available speeds in seconds/90° turn (locked rotor)

Model	Volts AC	0.33 Sec	2 Sec	5 Sec	10 Sec	15 Sec	30 Sec	60 Sec
MAR-9 & -10	120	—	0.75	—	0.70	—	0.65	0.65
	220	—	0.45	—	0.45	—	0.35	0.35
MAR-12 & -13	120	2.80	—	—	—	—	—	—
	220	1.00	—	—	—	—	—	—
MAR-24 & -25	120	—	—	—	0.75	—	0.65	0.65
	220	—	—	—	0.45	—	0.35	0.35
MAR-49 & -50	120	—	2.00	—	0.80	—	0.65	0.65
	220	—	0.95	—	0.50	—	0.45	0.45
MAR-89 & -90	120	—	—	1.75	—	0.60	—	—
	220	—	—	0.80	—	0.40	—	—

MODELS

MAR-100
MAR-160
MAR-250
MAR-800

With Manual Override



TORQUE RATINGS
(at 60Hz) in seconds/90° turn and torque in pound inches

Model	1.25 Sec	3 Sec	8 Sec	12 Sec	16 Sec	30 Sec	60 Sec
MAR-100	—	—	—	—	1500	1800	—
MAR-160	—	—	1920	—	2000	2500	—
MAR-250	—	3500	3000	—	4000	5000	5000
MAR-800	—	—	—	10,000	—	10,000	—

CURRENT RATINGS
in amps, at standard available speeds in seconds/90° turn (locked rotor)

Model	Volts AC	1.25 Sec	3 Sec	8 Sec	12 Sec	16 Sec	30 Sec	60 Sec
MAR-100	120	—	—	—	—	1.75	1.70	—
	220	—	—	—	—	0.80	0.75	—
MAR-120	120	7.00	—	—	—	—	—	—
	220	3.20	—	—	—	—	—	—
MAR-160	120	—	—	1.80	—	1.80	1.70	—
	220	—	—	0.95	—	0.90	0.75	—
MAR-250	120	—	7.00	2.50	—	2.50	1.75	1.70
	220	—	3.20	1.25	—	1.10	0.90	0.75
MAR-800	120	—	—	—	7.00	—	2.80	—
	220	—	—	—	3.20	—	1.25	—

NIBCO INC., ELKHART, INDIANA

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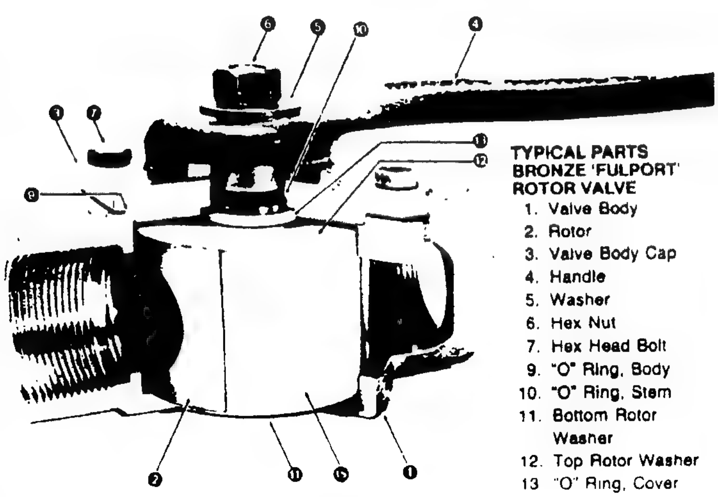
The following pages are applicable to: Ref. Section Four, (2 Way Valves) paragraphs 4.2.4.3 (Valve V2), 4.2.4.4 (Valve V12), 4.3.2.2 (Valve V14), 4.4.2.2 (Valve V15), 4.4.3.1 (Valve V3); (3 Way Valves) paragraphs 4.2.4.2 (Valve V10), 4.2.4.5 (Valve V1), 4.3.3.3 (Valve V8), 4.3.3.4 (Valve V9), 4.4.3.2 (Valve V4), 4.4.3.3 (Valve V5), 4.4.3.4 (Valve V13); (4 Way Valves) paragraphs 4.2.4.1 (Valve V11), 4.3.3.1 (Valve V6) and 4.3.3.2 (Valve V7):

The Versatile QCI Multi-ported, in Bronze or Stainless Steel,

The Chemical Processing and allied industries – Food, Beverage, Dairy, Drug, Hydrocarbon, Petroleum and Petrochemical – as well as Pulp and Paper processors, Utilities, Aerospace and other Original Equipment Manufacturers, have been using Quality Controls 'Fulport' Rotor Valves in increasing numbers since company beginnings in 1960. For good reasons.

QCI multi-port rotor valves are available in ¼" through 8" sizes in bronze or 316 stainless steel. With a wide variety of ends and the choice of manual, pneumatic or electric operation, QCI offers the design engineer the greatest possible selection of custom valves. Advantages include:



2-WAY VALVE

TYPICAL PARTS BRONZE 'FULPORT' ROTOR VALVE

1. Valve Body
2. Rotor
3. Valve Body Cap
4. Handle
5. Washer
6. Hex Nut
7. Hex Head Bolt
9. "O" Ring, Body
10. "O" Ring, Stem
11. Bottom Rotor Washer
12. Top Rotor Washer
13. "O" Ring, Cover
15. Seal, Solid

Multi-port selection – five flow combinations are available within the same envelope dimensions. Included are Straight Through 2-way (S), Right Angle (L) 3-port combination (T), LT and LL options.

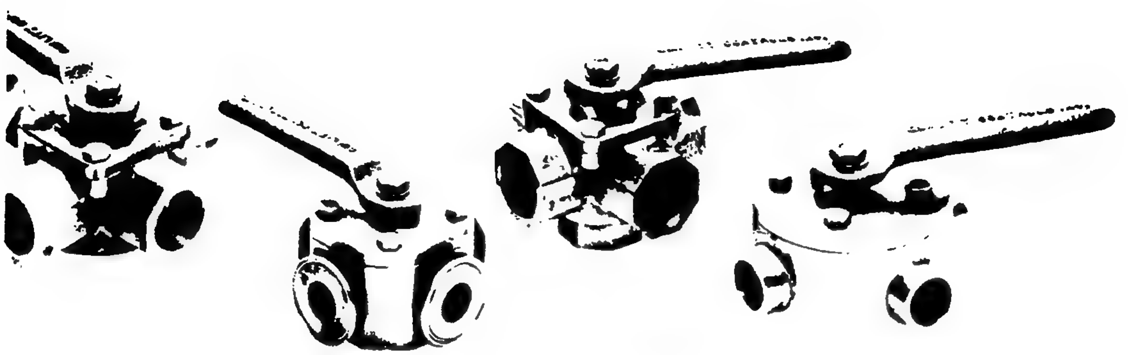
Full Port – inside diameter of port is consonant with inside diameter of pipe. No pressure drop across the valve. No obstructions . . . no turbulence.

Top Entry; In-Line Servicing – handle, cap rotor and seals lift out as a unit for easy maintenance. Valve removal from line never required.

FlexiSeals – leaf seals are precision-fitted to milled rotor slots to form a smooth, integral surface which is self-cleaning, self-lubricating and long-wearing. QCI will supply the leaf seals and O-rings in a wide range of materials (Teflon, Viton, Neoprene, Buna-N, Buna-S) to meet specific requirements of the media being handled. QCI patented FlexiSeals eliminate torque differential due to fluctuating temperatures. FlexiSeals perform exceptionally well handling abrasive materials, as their ability to flex eliminates the troublesome seizing experienced with other valves.

Cavity-free Chamber – leaf seal design eliminates all cavities common to the typical ball valve. No chance of residual crusting or sedimentation. Frequent purging unnecessary; no bacteria buildup.

Smooth Throttling – seats not exposed to wiredraw effect when in throttling position. Low coefficient of friction – low torque



'Fulport' Rotor Valve...
Custom Ends and Actuators for any service!

Quarter-turn Full Range – 90° turn of handle swings port from closed to full open position. Choice of pneumatic or electric actuators for automated systems (see pp. 6-7).

Unitized Stem and Rotor – one-piece construction eliminates a source of wear and repair. No stem leakage.

Compactness – demands little more space than outside diameter of pipe line in which installed.

Custom Ends – 'Fulport' Rotor Valves in bronze are available with threaded, flanged or brazed ends. Valves in 316 stainless steel are available with threaded, Tri-Clamp, socket-weld, butt-weld or flanged ends (pp. 4-7).

Tri-Clamp ends are a unique quick-couple union providing a turbulence-free non-contaminating, non-corrosive environment especially beneficial to the food and pharmaceutical industries. Inexpensive, compact, they have 'neuter' ends permitting fast takedown and reassembly without tools, and easy line alteration. They find an ideal application in the QCI 'Fulport' Sanitary Valve.

Transitional Flow – QCI Rotor design allows transitional flow to occur when changing valve positions eliminating dead heading and pumping problems. Non-transitional flow designs available.

Valve Life – The unique patented QCI valve design results in minimal valve maintenance. Repair kits and factory service are available.

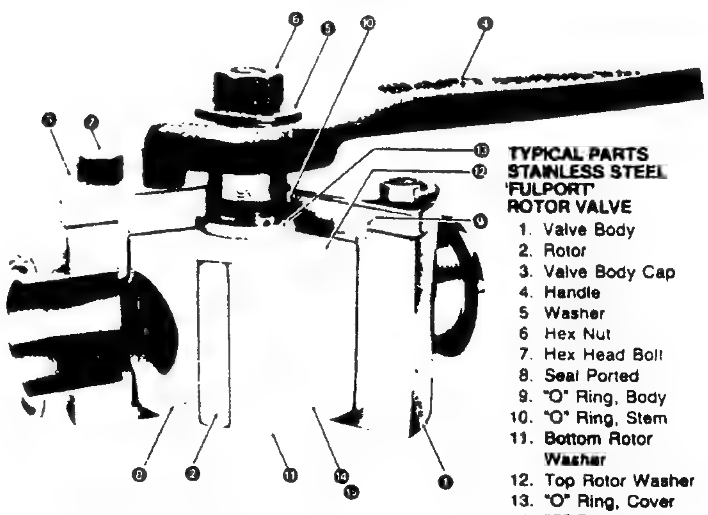
Multi-Ported Specials – 6 to 24 way specially ported valves are available.

Functionally Fire-safe – will hold in 'off' position even if seals become charred or melted by intense heat.

Laboratory Tested and Performance Proved – meets a broad range of pressure, temperature and corrosion conditions.

In a word, the special advantages of both ball and plug valves are designed into – and their deficiencies designed out of – the QCI 'Fulport' Rotor Valve. Wherever ball valves or plug valves might ordinarily be used, Rotor Valves perform better!

Specifications and ordering information are contained in the following pages. For additional facts and figures contact your Quality Controls distributor. Or call or write us.



MULTI-PORTED VALVE

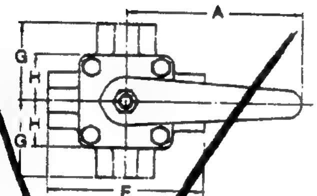
TYPICAL PARTS STAINLESS STEEL 'FULPORT' ROTOR VALVE

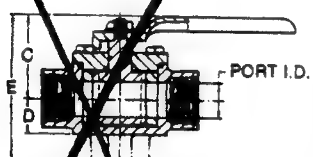
1. Valve Body
2. Rotor
3. Valve Body Cap
4. Handle
5. Washer
6. Hex Nut
7. Hex Head Bolt
8. Seal Ported
9. "O" Ring, Body
10. "O" Ring, Stem
11. Bottom Rotor Washer
12. Top Rotor Washer
13. "O" Ring, Cover
14. "O" Ring, Seal (As Required)
15. Seal, Solid

QCI 'Fulport' Rotor Valves
Bronze: 2-, 3-, 4-, 5-way

F.N.P.T. ends

5-WAY





DIMENSIONS: BRONZE VALVES

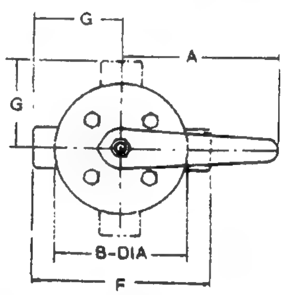
THREADED ENDS											
SIZE	A	C	D	E	F	G	H	PORT I.D. S	PORT I.D. L or T	PORT I.D. LL	WT
¼	3.88	[illegible]	.56	2.57	2.50	1.25	[illegible]	375	375	250	1.5
⅜	3.88	1.44	.56	2.57	2.50	1.25	60	375	375	250	1.5
½	[illegible]	1.44	.56	2.57	2.50	1.25	60	.500	375	.250	1.5
¾	5.06	1.76	.78	3.32	3.50	1.75	.94	[illegible]	688	500	2.5
1	5.31	2.31	1.00	4.13	4.38	2.19	1.31	1.00	1.00	750	5.5
1¼	5.31	2.50	1.00	4.25	4.62	2.31	1.31	1.00	[illegible]	750	6
1½	8.00	3.37	1.23	5.62	5.88	2.94	1.75	1.50	[illegible]	1.125	11
2	12.00	3.88	1.56	6.29	6.24	3.12	2.06	2.00	1.88	1.31	15.5
2½	12.00	4.25	2.00	8.63	8.00	4.00	2.62	2.50	2.50	1.75	37
3	13.50	5.25	2.75	9.43	10.36	5.10	3.88	3.00	3.00	3.00	52
4	16.00	7.62	3.12	12.14	12.00	6.00	5.00	4.00	4.00	4.00	80
6	22.50	9.00	4.53	AS REQ'D	16.25	8.12	6.25	6.00	6.00	6.00	100

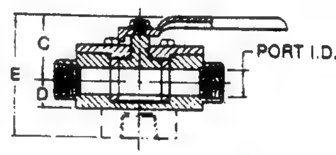
P.4

QCI 'Fulport' Rotor
Stainless & Carbo

choice of ends

2-WAY, THREADED





DIMENSIONS:

THREADED ENDS											
SIZE	A	B DIA	C	D	E	F	G	PORT I.D. S	PORT I.D. L or T	PORT I.D. LL	WT.
¼	3.88	2.75	1.50	.56	2.63	2.75	1.38	375	375	250	2.5
⅜	3.88	2.75	1.50	.56	2.63	2.75	1.38	375	375	250	2.5
½	3.88	2.75	1.50	.56	2.63	2.75	1.38	500	375	250	2.5
¾	5.06	3.50	1.76	.72	3.30	3.50	1.75	750	688	500	4.5
1	5.31	4.00	2.31	1.00	4.37	4.00	2.00	1.00	1.00	.750	8
1¼	5.31	3.50	2.31	1.00	4.37	3.50	1.75	1.00	1.00	750	8
1½	8.00	4.50	2.94	1.25	5.66	6.00	3.00	1.50	1.50	1.125	[illegible]
2	12.00	5.25	3.66	1.56	6.19	6.50	3.25	2.00	1.88	1.31	
2½	12.00	8.50	4.25	2.00	6.25	8.00	4.00	2.50	2.50	2.50	38
3	13.50	7.75	5.25	2.56	AS REQ'D	10.38	5.19	3.00	3.00	3.00	57
4	16.00	10.00	AS REQ'D	3.50	AS REQ'D	12.18	6.09	4.00	4.00	4.00	110
6	22.50	13.50	9.00	5.65	AS REQ'D	-		6.00	6.00	6.00	200

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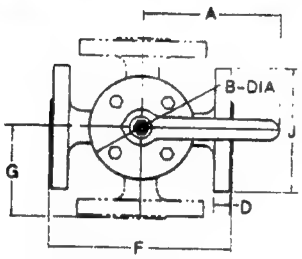
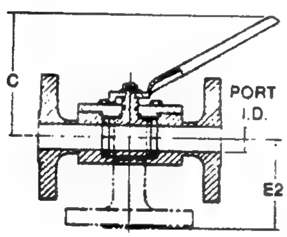
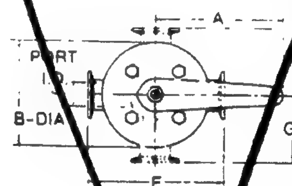
Valves
Steel: 2-, 3-, 4-, 5-way

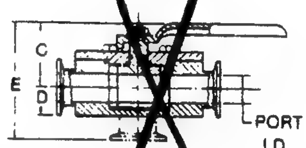
3-WAY; FLANGED

3-WAY, TRI-CLAMP









STAINLESS AND CARBON STEEL VALVES

150# FLANGED ENDS

SIZE	A	B DIA.	C	D	E	F	G	J	PORT I.D. S	PORT I.D. L or T	PORT I.D. LL	WT
½	3.88	2.75	2.87	.38	2.44	4.88	2.44	3.50	.500	.375	.250	5
¾	5.06	3.50	3.88	.44	2.78	5.88	2.94	3.88	.750	.688	.500	10
1	5.31	3.50	4.43	.50	2.88	5.75	2.88	4.25	1.00	1.00	.750	15
1¼	5.31	3.50	4.82	.58	3.25	7.00	3.50	4.82	1.00	1.00	.750	20
1½	8.00	4.50	5.88	.62	3.50	7.00	3.50	5.00	1.50	1.50	1.125	25
2	12.00	5.25	6.53	.68	3.88	7.75	3.88	6.00	2.00	1.88	1.31	30
2½	12.00	6.50	4.25	.88	4.00	9.50	4.75	7.00	2.50	2.50	2.50	40
	13.50	7.75	6.12	.88	5.50	10.75	5.38	7.50	3.00	3.00	3.00	100
4	18.00	10.00	6.87	.88	6.38	13.75	6.88	9.00	4.00	4.00	4.00	150
6	22.50	13.50	9.00	.94	8.75	18.00	8.00	11.00	6.00	6.00	6.00	250
8	30.00	18.00	12.06	1.06	10.50	24.00	12.00	13.50	8.00	8.00	8.00	400

P.5

TRI CLAMP ENDS

SIZE	A	B DIA	C	D	E	F	G	PORT I.D. S L.T	PORT I.D. LL	WT.
[illegible]	3.88	1.88	[illegible]	.56	2.68	3.25	1.50	[illegible]75	.250	2
	3.88	1.88	[illegible]50	.56	2.68	3.25	1.50	.37[illegible]	.250	2
	3.88	1.88	1.50	.56	2.68	3.25	1.50	.375	.250	2
[illegible]	5.06	2.7[illegible]	1.78	.72	3.10	4.00	2.00	.620	[illegible]00	3
1	5.31	3.[illegible]	2.31	1.00	3.31	4.32	2.17	.856	.75[illegible]	7
[illegible]	8.00	[illegible]50	3.44	1.25	5.19	5.56	2.78	1.358	1.125	12
	12.00	5.25	3.66	1.56	5.91	6.50	3.25	1.856	1.312	18
	12.0[illegible]	6.50	4.25	2.00	7.63	7.78	3.88	2.358	2.358	40
	1[illegible]	7.75	5.25	2.56	8.66	9.08	4.53	2.856	2.856	60
	[illegible]00	10.00	AS REQ'D	2.872	AS REQ'D	11.30	5.65	3.810	3.810	90
6	22.50	13.50	9.00	5.25	15.25	15.50	8.50	5.834	5.834	200

Dimensions may vary due to design changes. For exact dimesions contact factory.

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QCI 'Fulport' Rotor Valve Porting

Quality Controls rotor valves are available in two, three, four, and five-way configurations in a variety of porting arrangements. In addition to basic ordering information such as valve size, material, etc., the following should be specified:

- Port arrangement
- Number and sequence of rotor positions
- Direction of rotation

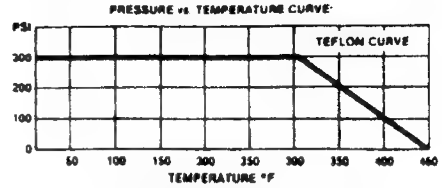
Number of Rotor Positions

For manual valves, two rotor position stops normally provide a motion of 90 degrees in any of the four quadrants. 180, 270, or 360 degree motion can be provided on request. For pneumatically and hydraulically actuated valves only three positions are possible, reversible over a 180 degree range in any of the paired quadrants. For electrically actuated two-way valves, two stops 90 degrees apart are provided. For electrically actuated three or four way valves, two, three, or four stops can be provided.

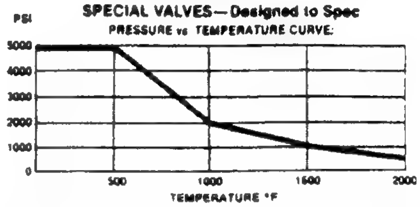
Rotor Positions and Sequences

A variety of rotor positions and sequences may be specified. The chart below shows rotor positions for each type of port arrangement, together with some of the typical sequences which may be specified.

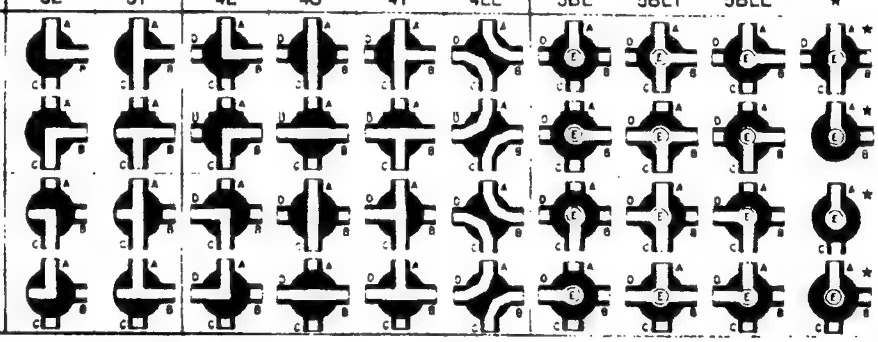
STANDARD VALVES
PRESSURE vs TEMPERATURE CURVE



SPECIAL VALVES—Designed to Spec
PRESSURE vs TEMPERATURE CURVE



TYPE	3-WAY		4-WAY				5-WAY			
PORTING	3L	3T	4L	4S	4T	4LL	5BL	5BLT	5BLL	★
Position 1										
Position 2										
Position 3										
Position 4										



★ Optional porting available

ORDERING CODE:

Body-Cap-Rotor	Code	O-Rings	Code
Bronze	1	Special mat.	6
316 Stainless Steel	2	Teflon	7
Carbon Steel	3	Viton	8
Special Alloy	4	Buna-N	9

Different Type Ends Available

Type—Example

FNPT	Female Pipe Thread	MA	Male Acme
FLG	Flanged	SW	Socket Weld
TC	Tri Clamp	BW	Butt Weld
CB	I Line	TB	Tank Bottom
SP	Special Design	PR	Proportioning Rotor

Multi-Port Rotor Combination

S Straight Through 2-way — L Right Angle — T Three-Port Combination — LL 2 Right Angle Ports — BL Bottom L

Available Series:

¼" through 10" valve sizes.

2119 S	3119 S or L or T	4119 S, L, T or LL	5119 BL, BLT, BLL or BT
2229 S	3229 S or L or T	4229 S, L, T or LL	5229 BL, BLT, BLL or BT

ORDERING INFORMATION:

Sample ordering codes for a ½" 2-way Bronze valve and a ¾" 3-way 316 Stainless Steel valve. Add R for reinforced seals. TC for Tri-Clamp ends.

Size	No. of Ports	Body & Cap Material	Rotor Material	'O' Rings	Rotor Design	Reinforced Teflon Leat Seals	Type
½"	2	1	1	9	S	–	–
¾"	3	2	2	7	T	R	TC

Quality Controls, Inc.
Route 3 Box 328
Tilton, NH 03276 / Phone (603) 286-3321

PBE
611 Moorefield Park Drive
Suite B
P.O. Box 35698
Richmond, Va. 23236
804-323-3519
800-992-4571

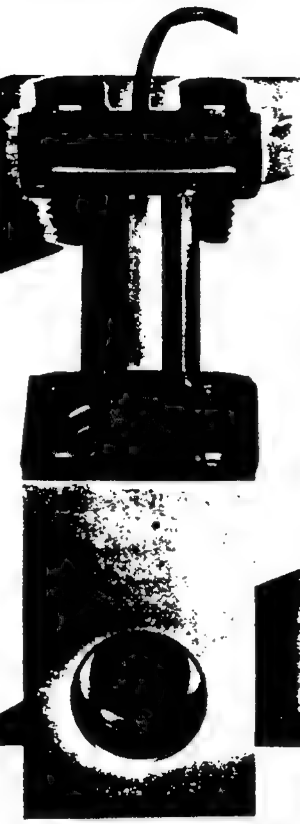
The following page is applicable to: Ref. Section Four, paragraph 4.5.1.8 (Sensor S15):

PADDLE WHEEL FLOW SEN
Stainless Steel

- For Liquids Containing up to 10% Suspended Particulate
- High Pressure and Temperature Design
- Wide Range: 1.5 to 30 FPS
- ±1% Sensor Accuracy*
- ±0.5% Full Scale Repeatability
- Easy to Install and Maintain

2 YEAR WARRANTY

$295



Model FP-5200 Paddle Wheel Sensor shown with Model FP-5205 Fitting.

MODEL FP-5200 SHOWN
For Compatible Instrumentation, See pages F-27 through F-35.

SPECIFICATIONS:

Output Signal: Sine wave @
Output Frequency: 15 Hz per ft./sec.
Output Amplitude: 0.4 V/FPS
Source Impedance: 10 K ohm
Range: 1.5 to 30 FPS
Accuracy: ±1% full scale
Repeatability: ±0.5% full scale
Maximum Pressure: 1500 PSIG
Maximum Temperature: 300°F (149°C)
Maximum Percentage of Solids: 10% fluid volume; particle size not exceeding 5 mm cross section or length
Materials: Rotor: CD4MCU SS; Rotor Housing: 347 SS; Rotor Shaft: 316 SS; Transducer Body: 347 SS; Top Flange: 347 SS; Cap: 347 SS
Rotor Bearing: Fluoroloy B (Teflon® based fluoroplastic)
Cable Length: 25 ft.

How To Order

1) Select Sensor by Pipe Size
2) Select Fitting for Pipe Diameter
3) Electronics—See Pages F-27 and F-31 through F-35

SENSORS ***HIGHLIGHTED MODELS STOCKED FOR FAST DELIVERY***

Model No.	Price	Accuracy*	Pipe Size
FP-5200	$295	± 1% full scale	0.5" to 1.25" Diameter
FP-5201	295		1.5" to 12" Diameter

INSTALLATION FITTINGS*

Model No.	Price	Pipe Size	Output (Hz/GPM)	Fitting Type
FP-5205	$160	0.5"	14.55	
FP-5207	160	0.75"	8.59	
FP-5210	160	1.00"	4.44	
FP-5212	160	1.25"	2.48	
FP-5215	160	1.50"	1.80	
FP-5220 FP-5225 FP-5230	160	2.00" 2.50" 3.00"	1.08 0.745 0.476	
FP-5240 FP-5260	160	4.00" 6.00"	0.272 0.1168	
FP-5280 FP-5281 FP-5282	160	8.00" 10.00" 12.00"	0.0661 0.0412 0.02816	

*Sensor accuracy can only be assured when the proper installation fitting is purchased with sensor. Sensors are calibrated with their respective fittings.

The OMEGA® Series FP-5200 Stainless Steel Flow Sensor is designed to accurately measure liquid flow at temperature and pressure levels beyond the capability of the standard Model FP-5300 Sensor. The stainless steel housing and rotor, and the durable compounded carbon-fiber impart unusual ruggedness to the design. When installed with OMEGA's mini-tap fitting its maximum operating pressure is 1500 PSI at a maximum temperature of 300°F (149°C).

These matched fittings provide plug-in accessibility in pipes from ½" diameter to a 12" diameter with an accuracy of ±1% of full scale.

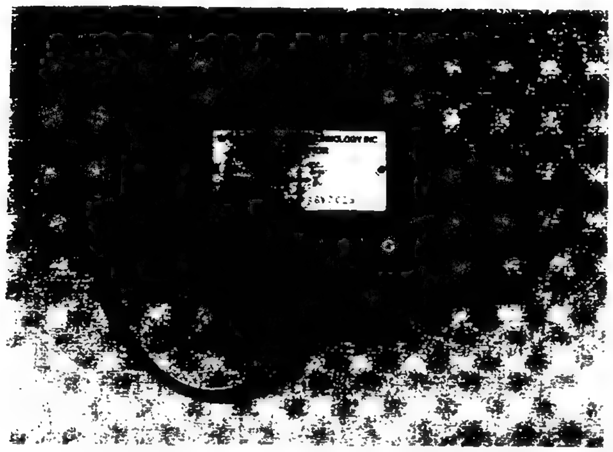
Ideally these sensors are suited for applications where corrosion resistance, high pressure, and high temperature conditions exist. The sensor is supplied with a mating connector and a 25 ft. cable.

All fittings are installed by welding.

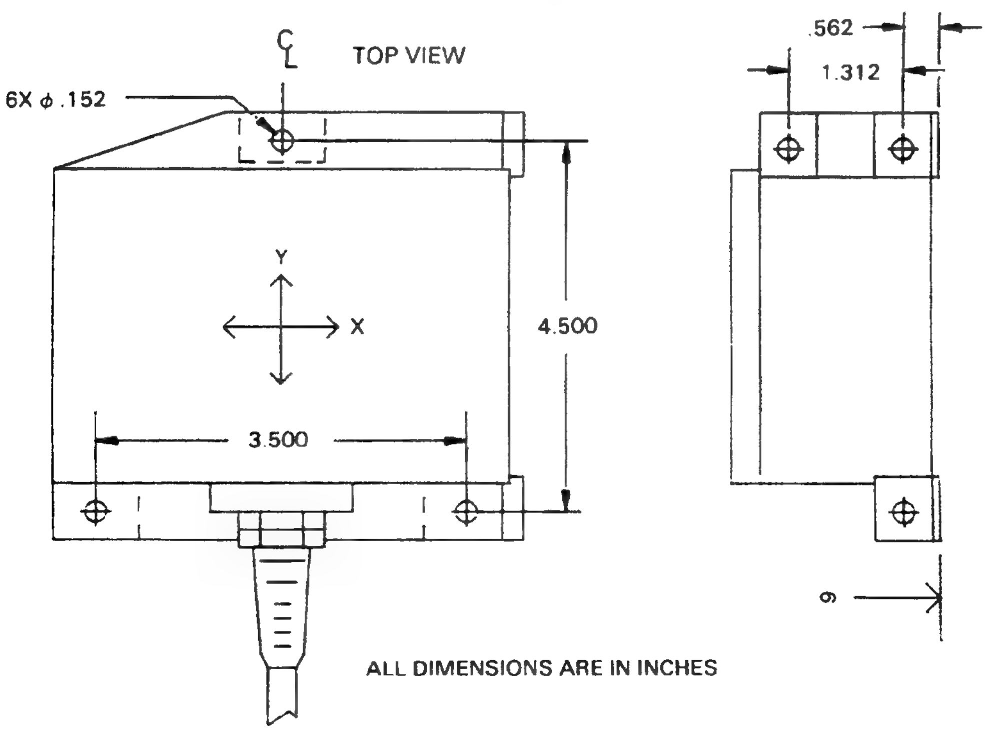
The following pages are applicable to the Attitude Sensor (Ref. Section Four, paragraph 4.5.1.11):

DUAL AXIS TILT MONITOR SSY0018

F 02-09

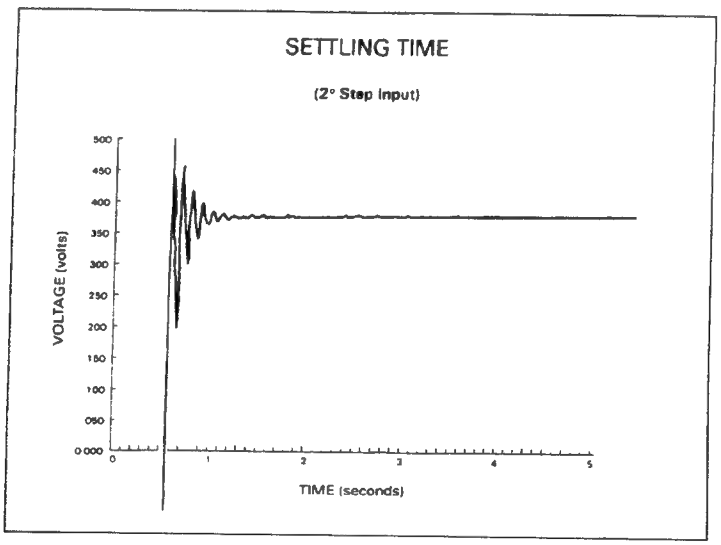


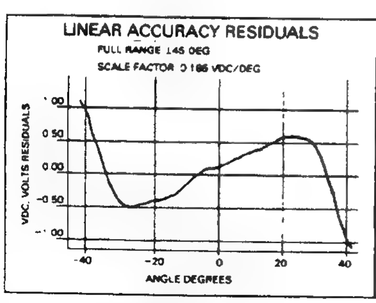
The SSY0018 dual axis tilt monitor combines Spectron's SP5000 sensor with signal conditioning in a waterproof package that is available with either strain relieved flying leads or molded connector. The enclosure has three mounting holes as well as null position reference surfaces to which the unit is factory calibrated.

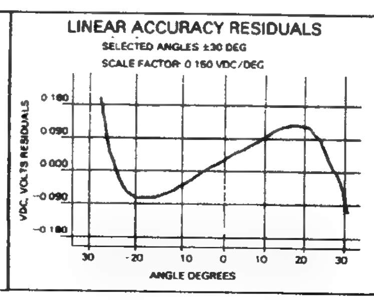


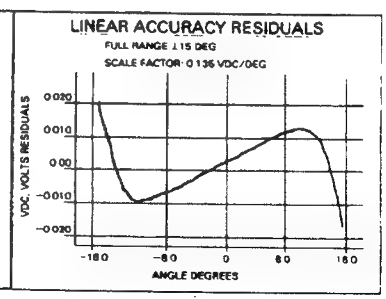
SSY0018:
Input Voltage: ±11v to ±16v DC
Power Required: .3w
Range: ±45°
Output Function: 150mv per degree
Repeatability: .01°
Operating Temperature: +80°c to 0°c
Settling Time: 500ms
Symmetry: at ±15° = 0.15 degree
Resolution: 0.005°

OPTIONS INCLUDE:
Molded connector (PKGN07GLLG Lemo)
Flying leads
Single ended power supplies
4 to 20ma output
Pulse width modulated output
Custom input voltage





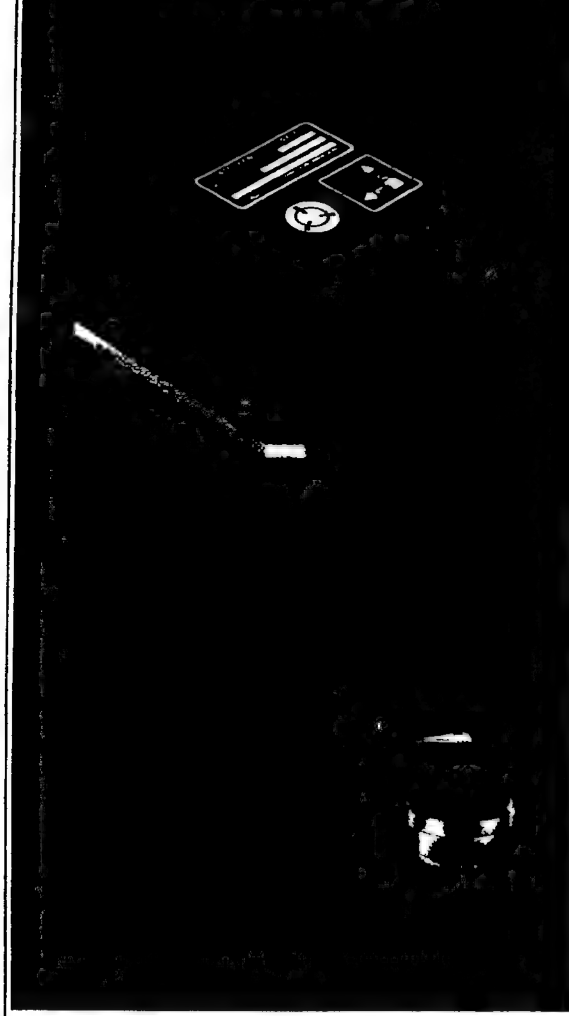




Spectron Systems Technology Inc.

595 Old Willets Path, P.O. Box 13368, Hauppauge, N.Y. 11788 Phone: (516) 582-5600 Fax: (516) 582-5671

CONDOR PACIFIC 2 AXIS RATE SENSOR ASSEMBLY



F-11-23

DESCRIPTION

The Condor Pacific 2 axis rate sensor assembly provides an accurate measure of angular rate by combining the Condor T-100 Gyro and the associated servo electronics. These electronics provide all the required functions to operate the gyro and provide a DC output signal that is proportional to the input rate.

The sensor package can measure input rate up to 120°/SEC. The servo loop bandwidth may be adjusted per customer requirement or up to 120 Hz. The analog output has a resolution of 0.05°/HR with optimum servo bandwidths.

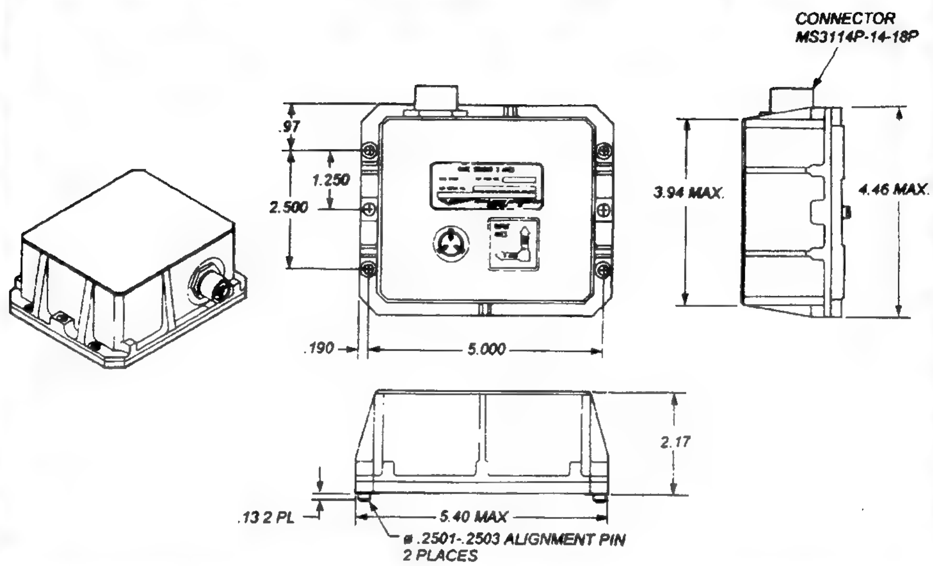
The sensor assembly contains the following elements:

1. A two axis T-100 gyroscope:
2. An optional DC to DC power supply with regulated +/- 15 volt outputs
3. A three phase square wave spin supply to drive the gyro spin motor
4. A digitally synthesized sinewave generator to excite the pickoffs.
5. A demodulator to convert the gyro pickoff output to DC, integrator, compensator, and filters for each gyro axis.
6. Restoring amplifiers to provide current to the gyro torquers.
7. The torquer current sensing resistor through a buffer amplifier provides rate output for each axis.

If desired, the gyro scaling resistor can be made available for a more precise output. In this case the actual current to the gyro torquer is measured. The scale factor is measured and supplied along with the sensor package. Under these conditions, the optimum accuracy and resolution of the gyro can be realized.

since 1964
CONDOR PACIFIC INDUSTRIES, INC.
31829 La Tienda Drive
Westlake Village, CA 91362 USA
Telephone: (818) 865-3000
FAX: (818) 865-3010

Reliability • Affordability • Accuracy



TWO AXIS RATE SENSOR

INPUT	- ± 15 VDC - 28 VDC (OPTIONAL)
POWER	- < 8 WATTS (QUIESCENT)
RANGE	- UP TO 120°/SEC STEADY STATE OR 300°/SEC STEADY STATE
BANDWIDTH	- 20 TO 120 Hz
RUN UP TIME	- 30 SEC
OUTPUT	- ±10 VOLTS FULL SCALE RATE
LINEARITY	- < 0.1% FULL SCALE
*NULL	- *NULL < 2°/HOUR
ACCELERATION SENSITIVE OUTPUT	- < 7°/HOUR/g
*RANDOM DRIFT	- < 0.1°/HOUR
AXIS ALIGNMENT	- 0.25 DEG
TEMP RANGE	- -40°C TO +71°C
WEIGHT	- 2.2 LBS
BUILT IN TEST	- SPIN MOTOR AND CAPTURE LOOP

*NULL, RANDOM DRIFT AND NOISE ARE DEPENDENT ON MAXIMUM RATE AND BANDWIDTH

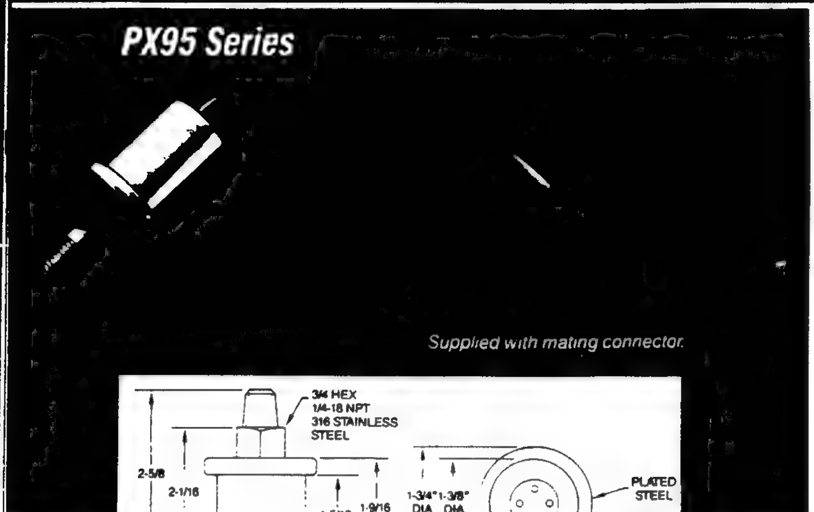
SIMILAR THREE AXIS RATE SENSOR PACKAGE AVAILABLE

The following page is applicable to: Ref. Section Four, paragraphs 4.5.1.4 (Sensor S16) and 4.5.1.7 (Sensor S1):

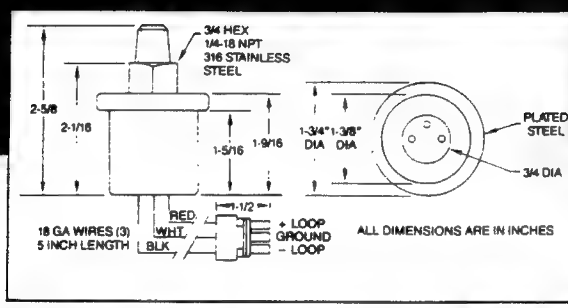
CORROSION RESISTANT PRESSURE TRANSMITTER

GAGE AND ABSOLUTE MODELS WITH 4 TO 20 mA OUTPUT

PX95 Series



Supplied with mating connector.



- Ideal for Applications With Gaseous or Liquid Media
- Temperature Compensated Over 0 to 50°C
- Gage Pressure, Silicon Diaphragm for Ranges of 100 PSI and Below
- Sealed Gage, Stainless Steel Diaphragm for Ranges of 300 PSI and Up
- Solid State Reliability

To Order *(Specify Model Number)*

	RANGE	MODEL*	PRICE	COMPATIBLE METER
SILICON DIAPHRAGM	0 to 5 PSIG	PX95-005GI	$175	DP2000P8, TX81, DP64
	0 to 10 PSIG	PX95-010GI	175	DP2000P8, TX81, DP64
	0 to 15 PSIG	PX95-015GI	175	DP2000P9, TX81, DP64
	3 to 15 PSIG	PX95-X15GI	175	DP2000P9, TX81, DP64
	0 to 30 PSIG	PX95-030GI	175	DP2000P8, TX81, DP64
	0 to 50 PSIG	PX95-050GI	175	DP2000P8, TX81, DP64
	0 to 100 PSIG	PX95-100GI	175	DP2000P8, TX81, DP64
	0 to 250 PSIG	PX95-250GI	175	DP2000P8, TX81, DP64
STAINLESS STEEL DIAPHRAGM	0 to 300 PSIS	PX95-300SI	210	DP2000P8, TX81, DP64
	0 to 500 PSIS	PX95-500SI	210	DP2000P8, TX81, DP64
	0 to 1000 PSIS	PX95-1KSI	210	DP2000P8, TX81, DP64
	0 to 3000 PSIS	PX95-3KSI	210	DP282C8, DP512C12, DP64
	0 to 5000 PSIS	PX95-5KSI	210	DP282C8, DP512C10, DP64
	0 to 300 PSIA	PX95-300AI	210	DP2000P8, TX81, DP64
	0 to 500 PSIA	PX95-500AI	210	DP2000P8, TX81, DP64
	0 to 1000 PSIA	PX95-1KAI	210	DP2000P8, TX81, DP64
	0 to 3000 PSIA	PX95-3KAI	210	DP282C8, DP512C12, DP64

SPECIFICATIONS

Excitation: 24 Vdc (9 to 28 V)
Full Scale Output: 20 mA
Full Scale Span: 16 mA
Zero Pressure Output: 4 mA
Static Accuracy: .25% Span ≤100 PSI; .50% Span ≥300 PSI, BFSL Linearity, Hysteresis, Repeatability
Span Temperature Effect: 1.0% Span
Zero Temperature Effect: 1.0% Span
Line Regulation: .005%V
Loop Resistance: 750 ohms
Response Time: 1 ms
Insulation Resistance: 50 megohms at 50 volts
Maximum Overpressure: 3 x full scale or 500 PSI ≤100; 3 x full scale or 10K PSI ≥300
Operating Temperature: 0 to 70°C
Storage Temperature: –40 to 125°C
Wetted Parts: ≤250 PSI Gold, Silicon, Glass and 316SS; ≥300 PSI 316SS
Weight: 6 oz.

B-61

The following pages are applicable to: Ref. Section Four, paragraphs 4.5.1.1 (Sensors S2 and S10) and 4.5.1.2 (Sensors S3 thru S9):

Optical Level Switches

These Compact Electro-Optic Units feature Self-Contained Solid-State Switching

- Small size
- Economically priced
- Built-in electronics
- No moving parts
- Simple, one-unit installation

NEW!

Typical Applications:

Medical laboratory • Food and beverage systems
Pharmaceuticals • Petrochemicals • Leak detection
Hydraulic reservoirs • Machine tools

GEMS ELS-1100 Level Switches are low cost, compact, optical level sensors with built-in switching electronics. With no moving parts, these small plastic units are ideal for a variety of point level sensing applications – especially where dependability and economy are a must.

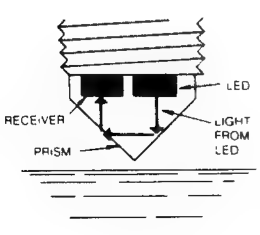
Of polysulfone construction, the ELS-1100 operates on 5 VDC or 10-28 VDC with 1 mm repeatability. The sensor offers broad liquid compatibility, however, it is not recommended for use in any liquid that crystallizes or leaves a solid residue.

These level switches are suitable for high, low or intermediate level detection in practically any tank, large or small. Installation is simple and quick through the tank top, bottom or side. Solid state switching ensures dependability over long service life.

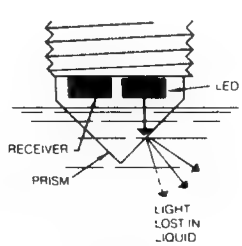
Simple Operating Principle

The electro-optical sensor contains an infrared LED and a light receiver. Light from the LED is directed into a prism which forms the tip of the sensor.

With no liquid present, light from the LED is reflected within the prism to the receiver. When rising liquid immerses the prism, the light is refracted out into the liquid, leaving little or no light to reach the receiver. Sensing this change, the receiver actuates electronic switching within the unit to operate an external alarm or control circuit.



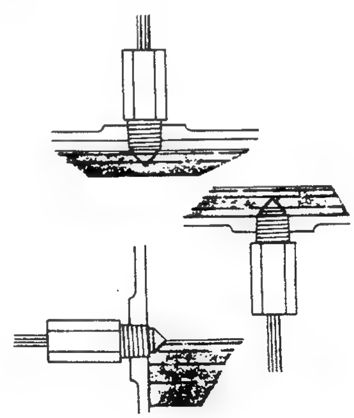
Liquid below the sensing prism



Liquid immersing the sensing prism

Installation and Maintenance

Installation of GEMS ELS-1100 Series Level Switches is extremely simple – through a 1/4" NPT in the top, bottom or side of the tank. Units may be installed in plastic or metal tanks, and must be positioned vertically or horizontally. If units are installed in tanks which are reflective on the inside surface (i.e., other than black), the prism tip should be mounted at least two inches from the tank top, bottom or side.



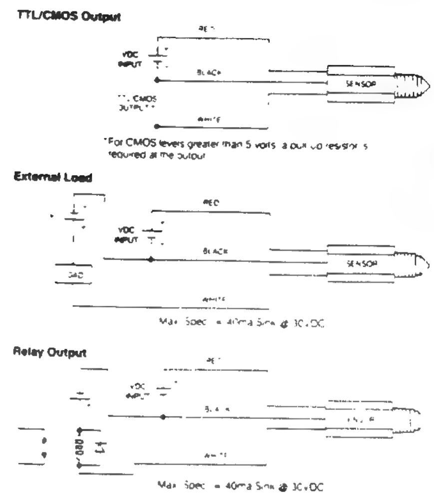
An occasional wipe-down cleaning of the prismatic tip of the sensor, with an appropriate cleaner, may be required if the liquid is excessively contaminated.

Optical Level Switches

Specifications:
Electrical Connections
Housing Material: Polysulfone*
Operating Temperature:
  5 VDC: +14°F to +176°F
  10-28 VDC: +32°F to +158°F
Operating Pressure: 0 to 150 psi, max.
Input Voltage: 10 to 28 VDC
  (Catalog Number A138167: 5 VDC ± 10%)
Current Consumption: 25 mA, approx.
Output: TTL/CMOS compatible, may sink 40 ma up to 30 VDC
Repeatability: ± 1mm
Lead Wires: #22 AWG. 12" to 14" extended

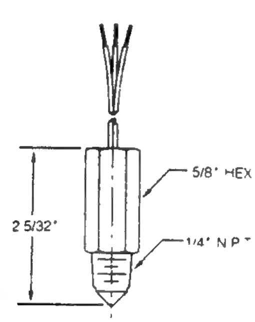
*Polysulfone is the only material normally in contact with the liquid If submerged, wetted materials will include epoxy, and PVC

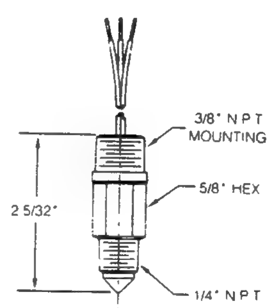
Electrical Connections

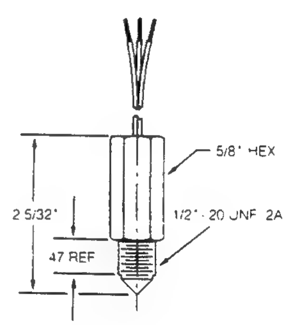


B

1/4" NPT				1/4" NPT with 3/8" Conduit			1/2" Straight Thread		







Switch Actuation	Order by Catalog Number									
Current Sink occurs when probe is:	10-28 VDC	Price Each	5 VDC	Price Each	10-28 VDC	Price Each	5 VDC	10-28 VDC	Price Each	5 VDC
Wet	142700*	$60.00	138167*	$55.00	143585	$65.00	Call	143580	$65.00	Call
Dry	143570	$60.00	—	—	143590	$65.00	—	143575	$65.00	—

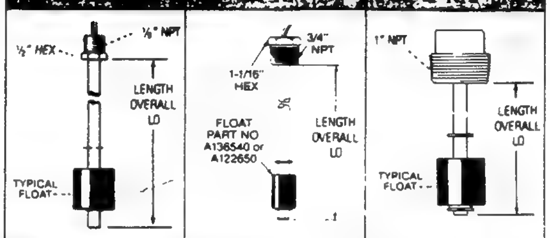
*In stock and ready for Express Service. All others require 4 to 6 weeks for delivery

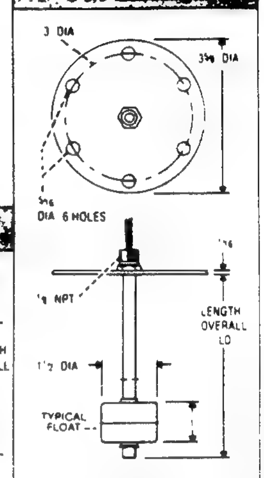
The following pages are applicable to: Ref. Section Four, paragraph 4.5.1.3 (Sensor S12):

Multi Level Switches

1. Tank Mounting/ Stem Types

Each Mounting Type (mounting thread configuration) can be customized with material and float choices and indicated in the tables below. However, Mounting Type 2 must be used with Float No. A136540 or A138030 only. Choose Mounting Type before going on to the other selections.

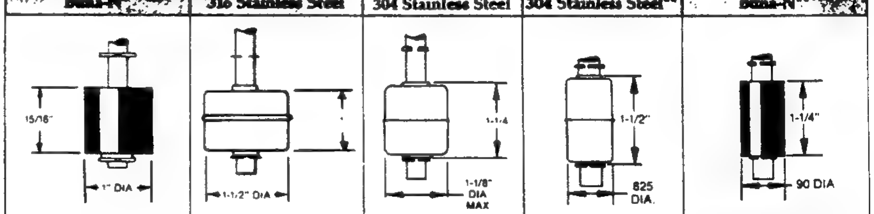




	Type 1	Type 2 3/4" NPT	Type 3 1" NPT	Type 4 3-3/8" Dia. Flange
Stem and Mounting Material	Brass or 316 Stainless Steel			
Float Catalog Numbers	A135230 A51974, A60241	A136540, A138030	A51974, A60241, A135230	
Maximum Length — LO	48"			
Mounting Position	Vertical ± 30° Inclination			
Float Stops	Brass Units: Beryllium Copper Grip Rings Stainless Steel Units: S.S. ARMCO PH-15-7MO Grip Rings			
Mounting Pressure Rating (Max.)*	300 psi	150 psi	300 psi	50 psi

*Maximum pressure rating for complete unit may be less than shown above based on the float selection shown below.

2. Float Types



	Catalog No. A51974, Buna-N*	Catalog No. A60241, 316 Stainless Steel	Catalog No. A135230, 304 Stainless Steel	Catalog No. A136540, 304 Stainless Steel**	Catalog No. A138030, Buna-N**
Operating Temperatures	Oil: − 40°F. to + 230°F. Water to + 180°F.	− 40°F. to + 300°F.	− 40°F. to + 300°F.	− 40°F. to + 300°F	Oil: − 40°F to + 230°F. Water to + 180°F.
Float Pressure Rating (Max.)*	150 psi	100 psi	300 psi	150 psi	150 psi
Minimum Liquid Specific Gravity	.65	.65	.98	.98	.60

*Other Wetted Material Hysol **Recommended for Type 2 Mounting configuration only.

3. Number of Actuation Levels and Electrical Specifications

Choose one float for each point at which you need a switch action to occur. The number of actuation levels available depends on type of wiring chosen. See tables below and at right.

	Group I Wiring	Group II Wiring
Number of Actuation Levels	1 to 5	1 to 3
Switch — SPST, N.O. or N.C.	20 or 100 VA	
Lead Wires	24"	

Typical Wiring Diagrams:

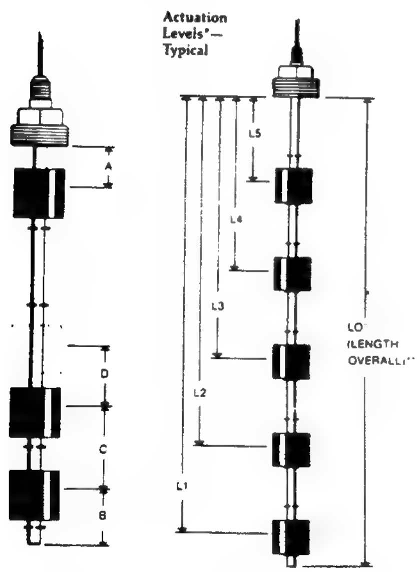
For clarity, two actuation levels only are shown in each group diagram.

Wiring Color Code:

SPST SWITCHES			
Wiring	Group I	Group II	
Unit Com.	[redacted]	None	
	NO/NC	SW Com.	NO/NC
L1	[redacted]	[redacted]	[redacted]
L2	[redacted]	[redacted]	[redacted]
L3	[redacted]	[redacted]	[redacted]
L4	[redacted]	Brown	Brown
L5	[redacted]	Orange	Orange

Notes:
1. Multi-point units included in shaded areas (above) can be supplied in UL recognized configurations
2. Units with 100 VA switches are not UL recognized
3. See Electrical Data, Page A-1

4. Actuation Levels and Dimensional Data



*Actuation level distances and LO (overall unit length) are measured from inner surfaces of mounting plug or flange.

**Length Overall (LO) = L1 + Dimension B. See Section I (Mounting Types) for Maximum Length values.

Calculate the switch actuation levels you'll require. Follow the guidelines below.

When using float Part Numbers A51974 and A60241:
A = 3/4" min. dist. to highest level.
B = 7/8" min. dist. from end of unit to lowest level.
C = 1-3/4" min. dist. between levels.
D = 1/8" min. dist. between level actuation points (nom. oper.)

When using float Part Number A135230:
A = 1-1/8" min. dist. to highest level.
B = 1-1/4" min. dist. from end of unit to lowest level.
C = 2" min. dist. between levels.
D = 1/8" min. dist. between level actuation points.

When using float Part Number A136540:
A = 1-9/16" min. dist. to highest level.
B = 1-11/16" min. dist. from end of unit to lowest level.
C = 2-7/16" min. dist. between levels.
D = 1/8" min. dist. between level actuation points (nom. oper.)

When using float Part Number A138030:
A = 7/8" min. dist. to highest level.
B = 1" min. dist. from end of unit to lowest level.
C = 2-1/16" min. dist. between levels.
D = 1/8" min. dist. between level actuation points.

The following pages are applicable to: Ref. Section Four, paragraph 4.5.1.5 (Sensor S11):

Thermocouple Head

A Connection Heads

OMEGA's standard connection head is the Model NSA. Designed to meet virtually all industrial needs. Connection heads provide the greatest protection for the electrical terminations of the transducer and associated instrumentation while maintaining easy access to the terminals.

The threaded cover is chained and fully gasketed for completely weatherproof installations. All OMEGA connection heads are available with either a single (2 wire) or a duplex (4 wire) terminal block. Any connection head shown on pages B-21 and B-22 can be used in an OMEGA Head and Well Assembly

B

Selection is made on the basis of operational requirements, accessibility, or avoiding direct contact with hot surfaces. Also, it is often required that the extension permit removal of the thermocouple element. For these requirements, OMEGA offers a complete line of configurations and component parts. OMEGA extensions are made of ½" NPT standard weight steel nipples and unions.

TYPE 1—DIRECT ASSEMBLY

A Type 1 assembly is used to connect the head to a protection tube. This type is only used with metal or ceramic protection tubes that have a male thread for direct assembly to a connection head. **Specify: Type 1**

TYPE 2—NIPPLE EXTENSION

A Type 2 assembly is used to connect the head to a thermowell. The length is measured from the bottom of the head to the top of the well. Available assembled in lengths of 0", ½" (13 mm), 1" (25.4 mm), 1½" (38 mm), 2" (51 mm), 2½" (64 mm), 3" (76 mm), 4" (102 mm), and 5" (127 mm). **Specify: Type 2-(length)**

TYPE 3—NIPPLE UNION EXTENSION

A Type 3 assembly uses a nipple and a union to connect a head with the male thread of a protection tube or fitting on a ceramic tube. Available assembled in lengths of 2" (51 mm), 2½" (64 mm), 3" (76 mm), 3½" (89 mm), 4" (102 mm), 4½" (114 mm), 5" (127 mm), 6" (152 mm), and 7" (178 mm). **Specify: Type 3-(length)**

TYPE 4—NIPPLE UNION NIPPLE EXTENSION

A Type 4 assembly consists of a union and two nipples, one threading into the head and one into the thermowell. This type permits easy removal of the head and element from the well. Available assembled in lengths between 2" (51 mm) and 12" (305 mm). **Specify: Type 4-(length)**

NON-STANDARD EXTENSIONS

Pricing—Add $2 for each additional 6" (152 mm), or fraction of 6" (152 mm) up to 48" (1219 mm). Over 48" (1219 mm), consult Sales Department. Example: Type 2-12 indicates Type 2 extension with 12" (304 mm) length. Pricing for standard Type 2 is $5, additional 7" (178 mm) nipple length is $4, total price $9.

Thermocouple Elements

OMEGA offers a complete line of thermocouple probes and elements, varying in diameter, type of junction, and configuration. Select elements from page B-9. A complete engineering group, staffed in depth by competent and experienced personnel, is ready to consult on any specific requirement employing thermocouple.

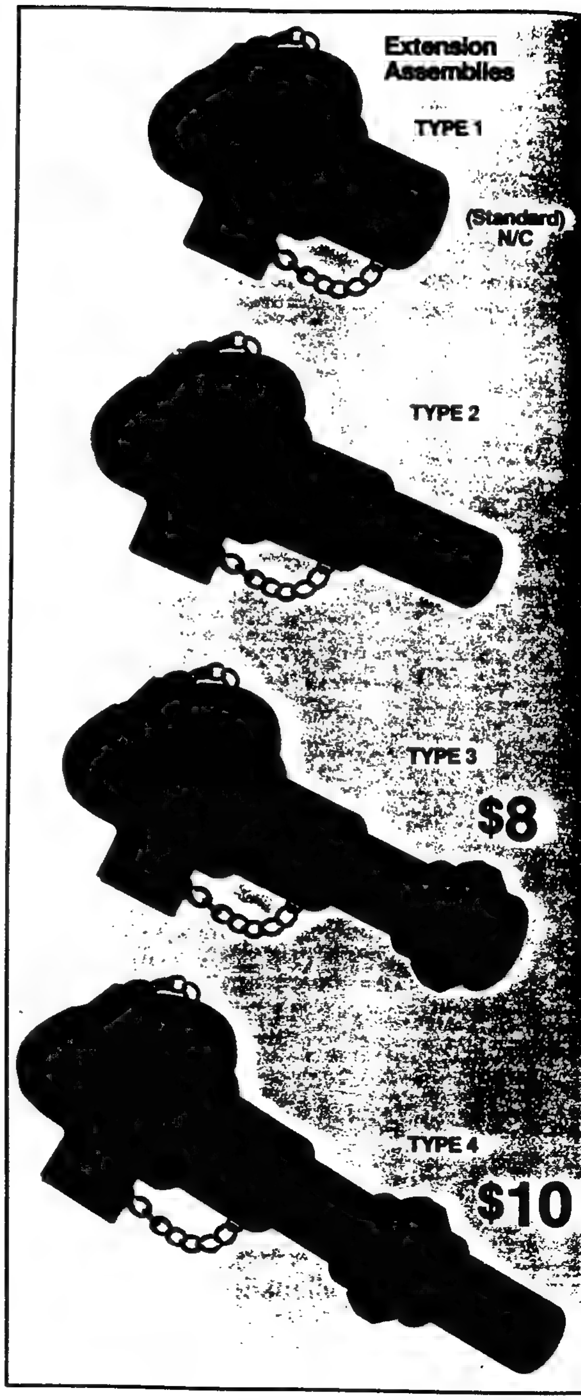
Thermowells

OMEGA offers the most complete line of standardized thermowells in the industry. Wells made of special materials are available upon request.

CAP and CHAIN Options: For Brass cap, add $4 to price and add suffix —CC (Brass) to the end of the catalog number.

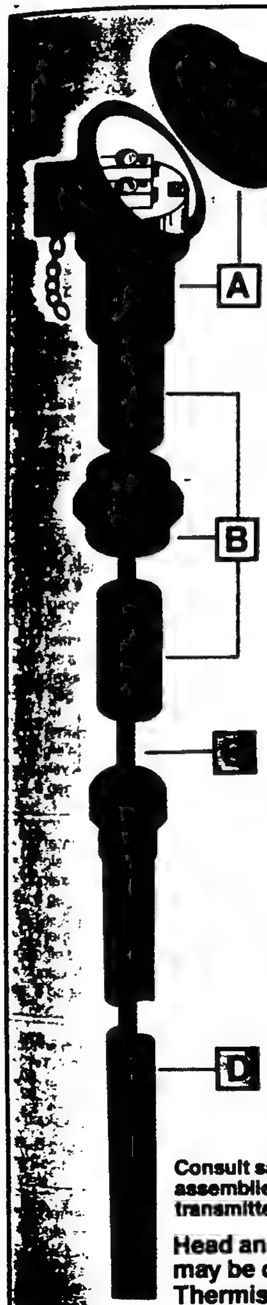
For 304SS cap, add $7 to price and add suffix—CC (304SS) to the end of the catalog number.

Consult sales for information on spring-loaded head probes.



and Well Assemblies

HOW TO ORDER HEAD AND WELL ASSEMBLIES



Consult sales for head and well assemblies with integral two-wire transmitters.

Head and Well Assemblies may be ordered for RTD's, Thermistors, or Thermocouples

Code HWA Signifies Head and Well Assemblies

Match Probe Length with the Insertion Length of the Thermowell

To assure a correct fit between the thermocouple assembly, dial thermometer or RTD and the thermowell into which it is inserted, OMEGA recommends that both the probe assembly and the thermowell be ordered at the same time if possible.

Most thermowells have female NPT threads for accepting and securing the male NPT pipe fitting of the inserted probe. Due to NPT (pipe thread) tolerances and torque variations during assembly, the probe may be set at various depths in the thermowell. For example, for a ½" NPT thread, these depth variations can be as much as ⅜" (9.5 mm) to ⅝" (15.9 mm). Ordering from OMEGA as a complete assembly avoids these variations.

STEPS FOR ORDERING A HEAD AND WELL ASSEM

1. To order a complete assembly from this section, star catalog descripton HWA. OMEGA will always check catalog number and pricing.
2. List the connection head desired. Type NB1-2 is thre for ½" NPT protection tube and has ½" NPT extens wire entry. NB1-2 is standard with OMEGA. If desirec other head styles and sizes are available. They are li on pages B-7 and B-8.
3. Specify the extension type from those listed on the opposite page. List extension length in inches, for example, 4-6 signifies a type 4 extension that is 6" (152mm) long.
4. Choose the thermocouple element from page B-9 and list that element part number. Specify "L" for length of the thermocouple element. The factory will cut the probe to insure a proper fit. Consult Sales Department for correct pricing and availability.

   Note: Besides the elements listed on page B-9, OMEGA offers a number of special element constructions. Elements can also be made from thermocouple wire and OMEGACLAD® listed in Section H. For dual element assemblies or other special element probes, consult OMEGA's Custom Assemblies Group.

5. Specify thermowell by giving catalog number from those listed on pages B-10 to B-26.

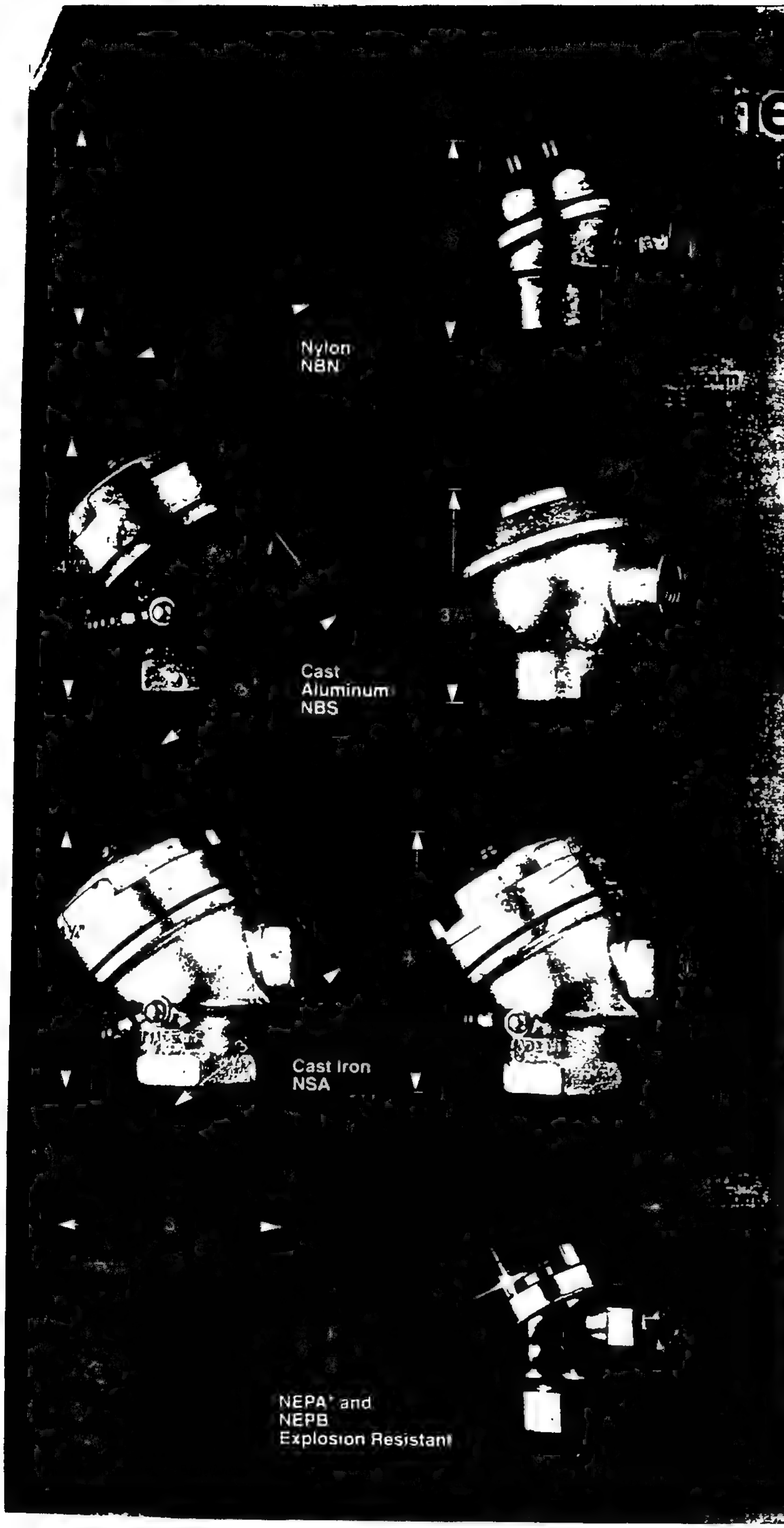
ORDER AS FOLLOWS:

COMPLETE CATALOG DESCRIPTION OF ASSEMBLY

HWA/NSA-2/4-6/DH-1-14-K-16/1"-385S/U7½-304SS

PRICE IS:

NSA-2 (HEAD)	**$25**
TYPE 4-6 (EXTENSION)	**10**
DH-1-14-K-16 (ELEMENT)	**14**
1"-385S-U7½-304SS (WELL)	**48**
TOTAL PRICE FOR COMPLETE ASSEMBLY	**$97**



ermocouple Heads

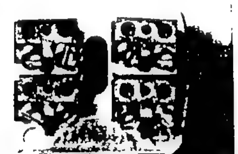
Material	Type	Model No.	Price Each
Nylon	NBN	NBN-0 NBN-2 NBN-4	$19 22 24
Die Cast Aluminum	NBB	NBB-0 NBB-2 NBB-4	$23 26 29
Cast Aluminum	NBS	NBS-0 NBS-2 NBS-4	$25 29 31
Cast Iron	NB1	NB1-0 NB1-2 NB1-4	$23 26 28
Cast Iron	NSA	NSA-0 NSA-2 NSA-4	$22 25 27
	NSB	NSB-0 NSB-2 NSB-4	$22 25 27
	NSC	NSC-0 NSC-2 NSC-4	$22 25 27
Cast Aluminum Body and Cap	NEPA	NEPA-0 NEPA-2 NEPA-4	$39 41 43
	NEPB	NEPB-0 NEPB-2 NEPB-4	$43 45 47
Cast Iron with Aluminum Cap	NEP-T	NEP-TX NEP-T0 NEP-T2 NEP-T4	$70 50 52 54
Burnished Die Cast Aluminum	NB2	NB2-0 NB2-2 NB2-4	$23 26 28

[illegible] use of explosion resistant heads does not imply that a complete [illegible] is either explosion proof or intrinsically safe. It is the user's [illegible] to determine suitability of materials for an installation.

Terminals	Weight (oz)	Tapped Openings: Protection tube entry	Tapped Openings: Extension wire entry	Features
= no terminal block 2 = single element 4 = duplex element Max. 14 gage wire	3 4 5	½" NPT	Supplied with nylon bushing for plastic covered extension wire to .240" - .400" O.D.	• Easy accessibility to terminal block • Suitable for use in ambient temperatures to 250° F • Moisture and dust-resistant • Ideal for chemical plant use • Excellent corrosion resistance • Very light weight
= no terminal block = single element = duplex element Max. 14 gage wire	6 7 8	½" NPT	½" NPT	• Good corrosion resistance • Light weight • Bayonet cover readily removed without tools • Easy accessibility to terminal block • Moisture and dust-resistant
= no terminal block = single element = duplex element Max. 8 gage wire	15 18 20	½" NPT	½" NPT	• Good corrosion resistance • Light weight • Cover equipped with safety chain, readily removed without tools • Moisture and dust-resistant
= no terminal block = single element = duplex element Max. 14 gage wire	22 23 24	½" NPT	½" NPT	• Rugged construction • Screw cover with inside thread • Moisture and dust-resistant • Ideal for outdoor use
= no terminal block = single element = duplex element Max. 8 gage wire	42 46 48	½" NPT	¾" NPT	• Rugged construction • Screw cover with inside thread • Moisture and dust-resistant • Ideal for outdoor use • Standard OMEGA heavy-duty head (NSC is not shown but in appearance is similar to the NSA and NSB heads.)
= no terminal block = single element = duplex element Max. 8 gage wire	40 44 46	¾" NPT	¾" NPT	
= no terminal block = single element = duplex element Max. 8 gage wire	36 40 42	1" NPT	¾" NPT	
= no terminal block = single element = duplex element Max. 8 gage wire	16½ 17¼ 18¼	¾" NPT	¾" NPT	• Explosion resistant Head • Rated for: Class I, Groups C, D Class II, Groups E, F, G Class III • Screw cover with inside thread • Moisture and dust-resistant • Ideal for outdoor use
= no terminal block = single element = duplex element Max. 8 gage wire	21½ 22¾ 23¼	½" NPT	½" NPT	
Contains mounting plates for 2WTXI 2-wire transmitter = no terminal block = single element = duplex element Max. 8 gage wire See Section L for other models	76 75 76¼ 76¾	½" NPT	½" NPT	• Explosion resistant head for 2-wire transmitter • Rated for: Class I, Groups C, D Class II, Groups E, F, G Class III • Screw cover with inside thread • Moisture and dust-resistant
= no terminal block = single element = duplex element Max. 12 gage wire	5 6 6½	½" NPT Standard	½" NPT internal thread w/compression fitting nut and rubber ferrule for 1/8" to 1/4" O.D. wire or tube	• Small and lightweight • Good corrosion resistance • Gasketed, weather resistant • Burnished finish • Safety chain on cover

Terminal Blocks for Connection Heads

CERAMIC BLOCK WITH NICKEL PLATED BRASS TERMINALS FOR NB2 HEAD. FOR GAGE 12 WIRE MAXIMUM			
MODEL NO. If Ordering Separately	TERMINALS	WEIGHT	PRICE
CH49 CH50	2 = single 4 = duplex	1 1/2 oz 2 oz	$4 6



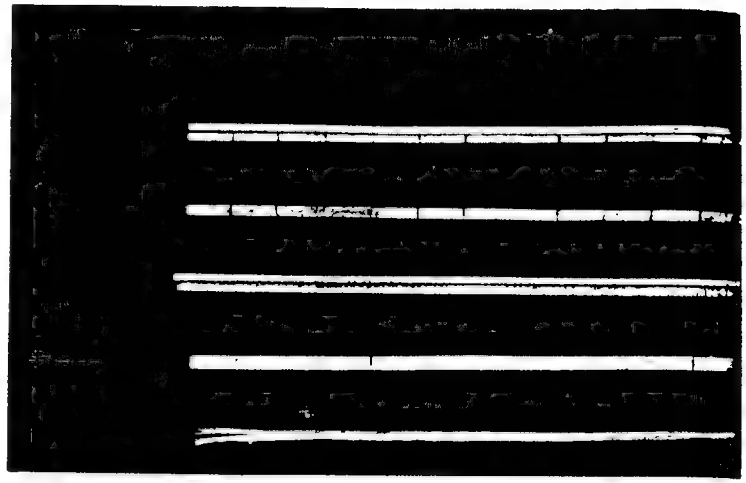
CERAMIC BLOCKS WITH BRASS TERMINALS FOR TYPE NSA, NSB, NSC & NBS CONNECTION HEADS FOR MAX. 8 GAGE WIRE			
MODEL NO. If Ordering Separately	TERMINALS	WEIGHT	PRICE
CH47 CH48	2 = single 4 = duplex	3 oz 4 1/2 oz	$6 8

CERAMIC BLOCKS WITH BRASS TERMINALS FOR TYPE NBN, NBI & NBB CONNECTION HEADS FOR MAX. 14 GAGE WIRE			
MODEL NO. If Ordering Separately	TERMINALS	WEIGHT	PRICE
CH73 CH74	2 = single 4 = duplex	1 1/4 oz 1 3/4 oz	$3 5

NEP-T Cast Iron with Aluminum Cap Explosion Resistant

Discount Schedule	
1-10 Units . . . Net	25-100 Units 10%
11-24 Units . . . 5%	101 and up . . Consult Sales

Thermocouple Elements



OMEGA's thermocouples are precise temperature measuring elements and are made of the highest grade materials available. They are carefully assembled according to the highest standards set by the industry. OMEGA's thermocouples are checked against standard temperature-millivolt curves to assure calibration accuracy and must match the accepted performance curves of the standard ANSI accuracy limits.

IRON-CONSTANTAN (J) CHROMEGA™-ALOMEGA™ (K) COPPER-CONSTANTAN (T) CHROMEGA™-CONSTANTAN(E)

BASE METAL THERMOCOUPLES (12" LONG PLUS 3" LEADS STANDARD)*

Type of Element	AWG Wire Size	Insulator Used	Type J Iron-Constantan	Price 12" Length	Price Add'l 6" or Fraction	Type K Chromega-Alomega	Price 12" Length	Price Add'l 6" or Fraction	Type T Copper-Constantan	Price 12" Length	Price Add'l 6" or Fraction	Type E Chromega-Constantan	Price 12" Length	Price Add'l 6" or Fraction
	8	None	Bare-8-J-12	$ 6	$ 2	Bare-8-K-12	$ 7	$ 2	Bare-8-T-12	$ 6	$ 2	Bare-8-E-12	$ 7	$ 2
	14		Bare-14-J-12	6	2	Bare-14-K-12	6	2	Bare-14-T-12	6	2	Bare-14-E-12	6	2
	20		Bare-20-J-12	6	2	Bare-20-K-12	6	2	Bare-20-T-12	6	2	Bare-20-E-12	6	2
rs)	24		Bare-24-J-12	6	2	Bare-24-K-12	6	2	Bare-24-T-12	6	2	Bare-24-E-12	6	2
	8	SH-1-8	SH-1-8-J-12	16	3	SH-1-8-K-12	16	3	SH-1-8-T-12	16	3	SH-1-8-E-12	16	3
lole	14	SH-1-14	SH-1-14-J-12	15	3	SH-1-14-K-12	15	3	SH-1-14-T-12	15	3	SH-1-14-E-12	15	3
	20	SH-1-20	SH-1-20-J-12	15	3	SH-1-20-K-12	15	3	SH-1-20-T-12	15	3	SH-1-20-E-12	15	3
rs	24	SH-1-24	SH-1-24-J-12	15	3	SH-1-14-K-12	15	3	SH-1-24-T-12	15	3	SH-1-24-E-12	15	3
	8	DH-1-8	DH-1-8-J-12	16	3	DH-1-8-K-12	16	3	DH-1-8-T-12	16	3	DH-1-8-E-12	16	3
Hole	14	DH-1-14	DH-1-14-J-12	15	3	DH-1-14-K-12	15	3	DH-1-14-T-12	15	3	DH-1-14-E-12	15	3
	20	DH-1-20	DH-1-20-J-12	15	3	DH-1-20-K-12	15	3	DH-1-20-T-12	15	3	DH-1-20-E-12	15	3
rs	24	DH-1-24	DH-1-24-J-12	15	3	DH-1-24-K-12	15	3	DH-1-24-T-12	15	3	DH-1-24-E-12	15	3
	8	FS-260-8	FS-260-8-J-12	16	3	FS-260-8-K-12	16	3	FS-260-8-T-12	16	3	FS-260-8-E-12	16	3
-lole	14	FS-200-14	FS-200-14-J-12	15	3	FS-200-14-K-12	15	3	FS-200-14-T-12	15	3	FS-200-14-E-12	15	3
Fish-Spine Insulators	20	FS-110-20	FS-110-20-J-12	15	3	FS-110-20-K-12	15	3	FS-110-20-T-12	15	3	FS-110-20-E-12	15	3
With Double Hole Oval Insulators	8	OV-1-8	OV-1-8-J-12	16	3	OV-1-8-K-12	16	3	OV-1-8-T-12	16	3	OV-1-8-E-12	16	3
	14	OV-1-14	OV-1-14-J-12	15	3	OV-1-14-K-12	15	3	OV-1-14-T-12	15	3	OV-1-14-E-12	15	3
	20	OV-1-20	OV-1-20-J-12	15	3	OV-1-20-K-12	15	3	OV-1-20-T-12	15	3	OV-1-20-E-12	15	3

NEW! NEXTEL CERAMIC INSULATION THERMOCOUPLE ELEMENTS

12" LONG WITH INSULATION, PLUS ½" STRIPPED ENDS STANDARD*

AWG Wire Size	Type K Temp. Range −300 to 2200°F	Price 12" Length	Price Add'l 6" or Fraction	Type E Temp. Range −300 to 1600°F	Price 12" Length	Price Add'l 6" or Fraction	Type J Temp. Range −300 to 1400°F	Price 12" Length	Price Add'l 6" or Fraction
14	XC-14-K-12	$15	$2	XC-14-E-12	$15	$2	XC-14-J-12	$15	$2
20	XC-20-K-12	13	2	XC-20-E-12	13	2	XC-20-J-12	13	2
24	XC-24-K-12	13	2	XC-24-E-12	13	2	XC-24-J-12	13	2

OPTIONAL LENGTHS

*When ordering, change the last digits (-12) to show actual length in inches.
Standard is a general purpose bead welded, exposed junction thermocouple. Temperature limitation is type thermocouple material. Nextel ceramic insulation continuous rating is 2200°F, short term rating 2600°F

See page A-14 for more information on Nextel insulated thermocouple elements.

Optional Lengths Available

When ordering, change the last digits (-12) to show actual length desired in inches and fractions.

Insulation Temperature Ratings*	
XC	2200°F
SH	1600°C
DH	1600°C
FS	1200°C
OV	1600°C

*Insulation only. Check operating limits of wire.

Series 260S

Standard Threaded Well for 1/4" Diameter Elements

Application:
Standard Length, 1/4" Stem, Bimetal thermometers; #20 gage thermocouple elements; unarmored liquid-in-glass test thermometers. Other temperature sensing elements having .252 in. maximum diameter.

Connection Size:
1/2", 3/4" and 1" NPT are standard. Other thread sizes are available upon request.

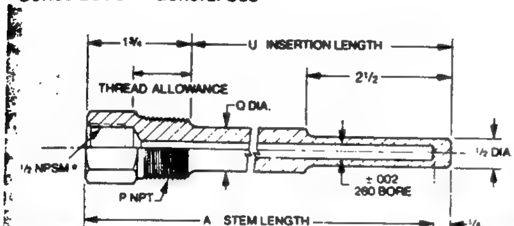
Protective Coatings For Thermowells—
- Resist Corrosion • For Chemical Baths
- Color-Coded Sensors for Process Control
- Available in PFA Teflon®, Epoxy and other materials

Please consult our Sales Department for complete information.

Materials:
Brass (ASTM B-16); Carbon Steel (C-1018); Stainless Steel A.I.S.I. 304 & A.I.S.I. - 316; Monel. Wells are available also in special materials, prices on request.

Cap and Chain Options: For Brass cap, add $4 to price and add suffix—CC (Brass) to the end of the catalog number.
For 304SS cap, add $7 to price and add suffix—CC (304SS) to the end of the catalog number.

Series 260S — General Use



All dimensions are in inches.

*NPSM internal pipe thread will accept both NPT and NPS male threads

◆ When ordering probes with NPT Fittings specify this stem length.

	1/2 -260S -U 2½ □	[illegible]	2½	—	$ 22.00	$ 30.00	$16.50	$16.50
Most Popular Sizes ▶	-U 4½ □	6	4½	5/8	26.50	36.00	20.00	20.00
	-U 7½ □	9	7½		39.50	53.00	31.50	31.50
1/2" NPT	-U10½ □	12	10½		48.00	65.00	41.00	41.00
	-U13½ □	15	13½		69.00	93.00	53.00	53.00
	-U16½ □	18	16½		82.50	111.00	63.50	63.50
	-U22½ □	24	22½		106.00	143.00	74.00	74.00
	3/4 -260S -U 2½ □	4	2½	—	22.00	30.00	16.50	16.50
Most Popular Sizes ▶	-U 4½ □	6	4½	3/4	26.50	36.00	20.00	20.00
	-U 7½ □	9	7½		39.50	53.00	31.50	31.50
3/4" NPT	-U10½ □	12	10½		48.00	65.00	41.00	41.00
	-U13½ □	15	13½		69.00	93.00	53.00	53.00
	-U16½ □	18	16½		82.50	111.00	63.50	63.50
	-U22½ □	24	22½		106.00	143.00	74.00	74.00
	1 -260S -U 2½ □	4	2½	—	29.00	35.50	22.00	22.00
Most Popular Sizes ▶	-U 4½ □	6	4½	7/8	36.50	49.00	26.50	26.50
	-U 7½ □	9	7½		48.00	65.00	34.50	34.50
1" NPT	-U10½ □	12	10½		60.00	80.00	46.00	46.00
	-U13½ □	15	13½		83.00	111.50	61.00	61.00
	-U16½ □	18	16½		97.00	130.50	71.50	71.50
	-U22½ □	24	22½		132.50	164.00	83.00	83.00

Material - 304 S S Carbon Steel, etc
Insertion length dimension
Bore size - inch
External thread - NPT

HIGHLIGHTED MODELS STOCKED FOR FAST DELIVERY.

Pressure-Temperature rating – lbs. per sq. inch

Brass	5000	4200	1000	—	—	—	—
Carbon Steel	5200	5000	4800	4600	3500	1500	—
A.I.S.I. - 304	7000	6200	5600	5400	5200	4500	1650
A.I.S.I. - 316	7000	7000	6400	6200	6100	5100	2500
Monel	6500	6000	5400	5300	5200	1500	—

See Page B-27 for Maximum Fluid Velocity.

These wells are compatible with OMEGA® NB1, NB2 (pgs. A-83, A-84), PR12, PR14 (pg C-7), and NPT style probes (pg. A-86), as well as DialTemp™ Thermometers (Section E).

To order, please specify: 1. Complete Type Number
2. Material
3. Cap & Chain — If Desired

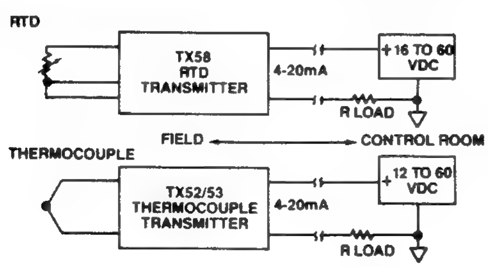
Increase Response Rate! Use OT-201 Conductive Silicon Paste (See page F-18)

1-10 .... Net
11-24 .... 10%
25-100 .... 20%
101 and up ... Consult Sales

Discounts apply to similar thermowell types

2 Wire Transmitter

Mounting track: $2/ft.
Catalog No. RT-[*]
*Sold in multiples of 4 ft lengths.



Transmitters provide a two-wire output with the same wiring used for power and output. The load resistance is connected in series with a dc power supply, and the current drawn from the supply is the 4-20mA output signal which is proportional to the input signal.

Two-wire current transmission permits remote mounting of the transmitter near the sensor to minimize the effects of noise and signal degradation to which low level sensor outputs are susceptible.

A rugged metal enclosure, suitable for field mounting, offers environmental protection and screw terminal input and output connections. This enclosure may be either surface or standard relay track mounted.

- **Thermocouples**
  OMEGA models TX52 and TX53 are high performance, low cost temperature transmitters designed to accept a thermocouple input from types J, K or T and produce a standard 4-20mA output cur
  The TX52 features high inpu output isolation (600 V rms) an high CMR (160dB @ 60 Hz). The TX53 offers a functional equivalent design without in output isolation.
- **Platinum RTD**
  Model TX58 accepts 2-wire 3-wire 100Ω platinum resist sensors (α = 0.00385 Ω/Ω/ and provides a linearized ou
- **AD590 Sensors:** Model TX accepts AD590 Solid State See Pages F-15 and F-16.

In Stock for Immediate Delivery

Specifications

Output Specifications	
Output Span	4-20mA
Minimum Output Current	3.5mA, typ
Maximum Output Current	40mA, typ
Output Protection[1]	±60V
Accuracy	
Total Output Error[2]	±0.1%
Stability vs. Ambient Temperature	−30 to 85°C
Zero	±0.038°C/°C max
Span	±0.005%/°C
Stability vs. Time[2]	±50ppm/Month
Warm-up Time to Rated Performance	3 Minutes
Response Time	
To 90% of Span	0.4 sec
Environmental	
Temperature Range, Rated Performance	−30°C to +85°C
Storage Temperature Range	−55°C to +125°C
Relative Humidity, Non-condensing	0 to 90%
RFI Effect (5W @ 470MHz @3 ft.) Error	±0.5% of Span
Physical	
Case Size	4" × 3.25" × 1.25"
Weight	8 oz. (227 grams)

NOTES
[1] Protected for reverse polarity and for any input/output connection combination
[2] Accuracy is specified as a percent of output span (16mA). Accuracy spec includes combined effects of transmitter repeatability, hysteresis and linearity. Does not include sensor error.
Output Impedance: $RL_{MAX} = \frac{(V_s - 16\ V)}{20\ mA}$

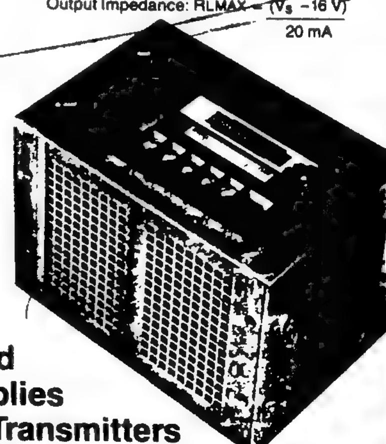
ANGES AVAILABLE

ensor Type	Range Code	Input Ranges	
Thermocouple er-Constantan)	T1 T2	−100°C to + 300°C 0°C to + 200°C	−148 to + 572°F + 32 to + 392°F
Thermocouple -Constantan)	J1 J2 J3	0°C to + 500°C −100°C to + 300°C 0°C to + 750°C	+ 32 to + 932°F −148 to + 572°F + 32 to +1382°F
Thermocouple mel-Alumel)	K1 K2 K3	−100°C to + 300°C 0°C to + 600°C 0°C to +1000°C	−148 to + 572°F + 32 to +1112°F + 32 to +1832°F
Platinum 000 RTD = 0.00385)	Pt1 Pt2 Pt3 Pt4	−100°C to + 100°C 0°C to + 100°C 0°C to + 200°C 0°C to + 400°C	−148 to + 212°F + 32 to + 212°F + 32 to + 392°F + 32 to + 752°F
AD590 olid State Sensor	—	− 55°C to + 150°C	− 67 to + 302°F

How to Order

d (Input to Output) Thermocouple Range X52-[*]	$295
olated Thermocouple Range X53-[*]	210
m RTD Range—non-isolated -[*]	229
Input	134

Code



Unregulated Power Supplies For 2-Wire Transmitters

Model Number	Price	Output
U24Y100	$120	24 Vdc, 1000 mA
U48Y40	130	48 Vdc, 400 mA

110 Vac power, −10 to 65°C operating range

N

APPENDIX C

FAILURE/HAZARD MATRIX

This Matrix lists the probable hazards and mission interruptions which result from design irregularities, component failures and/or human errors. The presentation is divided into three parts: Component Failure Results and Hazards; Operational Hazards; and Maintenance Hazards.

Personnel Hazards and Mission interruptions may result from the loss or failure of FARV Fuel System components. An analysis was performed to determine the severity and result of such failures at the component level. The results listed are those that occur when the component fails to operate as directed during differing situations and in conjunction with other component failures.

No "recommendations and control," nor "corrective action taken," is listed due to the conceptual stage of design development. Such actions and recommendations reflect actual design or fabricated and assembled material. All of the Results/Hazards outlined herein will carry an "open" classification for resolution at a later date.

The Risk Assessment listed is that applicable to the "Worst Case Scenario." The Risk Assessment ranking and classification method depicted reflects the requirements of MIL-STD-882C, Appendix A, Figure 2. The severity and probability classification is ranked according to the following Risk Assessment Matrix:

RISK ASSESSMENT MATRIX

FREQUENCY OF OCCURRENCE	I CATASTROPHIC	II CRITICAL	III MARGINAL	IV NEGLIGIBLE
(A) Frequent	1A	2A	3A	4A
(B) Probable	1B	2B	3B	4B
(C) Occasional	1C	2C	3C	4C
(D) Remote	1D	2D	3D	4D
(E) Improbable	1E	2E	3E	4E

The following definitions apply to the above MATRIX:

(I) CATASTROPHIC - Failure which may cause death or System loss.

(II)	CRITICAL	- Severe injury, illness or Mission Abort. Severe personnel injury and/or illness generally applies to permanent or long term disability (e.g., blindness, loss of limb, 3rd degree burns, lung/heart disease or damage). Equipment or component failures which prevent the system from attaining Mission requirements, or put the entire combat system in jeopardy.
(III)	MARGINAL	- Minor injury, illness or Mission curtailment. Minor personnel injury and/or illness generally applies to short term disability (e.g., contusions, lacerations, abrasions, temporary sight or hearing loss, shock). Equipment or component failure which diminishes the system capabilities or disables secondary functions or Mission requirements.
(IV)	NEGLIGIBLE	- Generally applies to failures which do not adversely affect personnel or system primary functions.
(A)	Frequent	- Likely to occur frequently.
(B)	Probable	- Will occur several times over the life of the item.
(C)	Occasional	- Likely to occur at some point in the life of the item.
(D)	Remote	- Unlikely, but possible to occur over the life of the item.
(E)	Improbable	- So unlikely, it can be assumed occurrence will not be experienced.

I. FARV Fuel System
Component Failure Analysis

Item	Description of Failure	Risk Assessment		Result/Hazard
		Cat.	Prob.	
1.	Inoperable Refuel/ Defuel Valve (V1)	III	E	1. Refuel capability negated 2. Refuel/Defuel rates reduced 3. Pressurized FTM Pump housing, FTM Fuel Filter/ Separator and robotic arm fuel lines 4. No effect on Refuel/Defuel capability or capacity 5. Diagnostics impeded
2.	Inoperable Tank Shut Off Valve (V2)	II	E	1. Fuel capacity reduced by approximately one third 2. Tank Refuel/Defuel rate reduced 3. Loss of ullage 4. Fuel in vent manifold and tubing 5. Fuel overflow and spill through vent aperture 6. Diagnostics impeded
3.	Inoperable Tank Transfer Valve (V3)	III	E	1. AFAS refuel capability reduced by one third 2. AFAS refueling rate reduced 3. Fuel pressurization of FTM components and robotic arm fuel lines 4. No effect on SARS Refuel/ Defuel capability or capacity 5. Diagnostics impeded

Item	Description of Failure	Risk Assessment		Result/Hazard
		Cat.	Prob.	
4.	Inoperable Pump Inlet Valve (V4)	II	E	1. AFAS refueling capacity negated 2. AFAS refueling rate reduced 3. No effect on AFAS refueling capability 4. "Other vehicle" defueling capability negated 5. "Other vehicle" defueling rates reduced 6. Other vehicle defueling unaffected 7. Diagnostics impeded
5.	Inoperable Pump Outlet Valve (V5)	II	E	1. AFAS refueling capacity negated 2. AFAS refueling rate reduced 3. No effect on AFAS refueling capability 4. On-board fuel transfer capability negated 5. On-board fuel transfer rates reduced 6. No effect on tank to tank transfer 7. Diagnostics impeded
6.	Inoperable Selector Valve, Tank Supply (V6) 4-Way	II	D	1. Availability of fuel reduced by approximately 60% (single source) 2. Availability of fuel negated
7.	Inoperable Selector Valve, Tank Return (V7) 4-Way	III	D	1. Control of fuel temperature negated 2. VFM Fuel Pump overpressure and over temperature
8.	Inoperable Supply Valve (V8) 3-Way	II	D	1. Fuel denial to APS 2. Fuel denial to Main Propulsion Unit 3. No operational effect

Item	Description of Failure	Risk Assessment		Result/Hazard
		Cat.	Prob.	
9.	Inoperable Return Valve (V9) 3-Way	III	D	1. Pressurized APS supply line 2. Pressurized Propulsion unit supply line 3. No operational effect
10.	Inoperable Vent Diverter Valve (V10)	III	E	1. Over-pressure Vent Manifold and Tubing 2. Refuel/Defuel capability negated 3. AFAS Refueling negated 4. Diagnostics impeded
11.	Inoperable Vent Selector Valve (V11)	III	E	1. Over-pressure Vent Manifold and Tubing 2. Refuel/Defuel capability negated 3. Vacuum on VFM components, power loss 4. Diagnostics impeded
12.	Inoperable Tank Drain Valve (V12)	III	D	1. Excess sediment and water in sump 2. Tank rendered unusable
13.	Inoperable Trans-Shipment Valve (V13)	III	D	1. Refuel/Defuel capacity negated 2. Tank to Tank transfer of fuel negated 3. Diagnostics impeded
14.	Inoperable Drain Valve, VFM Filter/Separator (V14)	III	E	1. Excessive water build-up in housing 2. Inoperable Filter/Separator unit with fuel spillage
15.	Inoperable Drain Valve, FTM Filter/Separator (V15)	III	E	1. Excessive water build-up in housing 2. Inoperable Filter/Separator unit with fuel spillage
16.	Mechanical Failure - any Valve (leaks, rupture, etc.)	I	D	1. Fuel or vapor release to the chassis interior 2. Activation of Fuel/Vapor Sensor 3. Inoperable FARV Fuel System

Item	Description of Failure	Risk Assessment		Result/Hazard
		Cat.	Prob.	
17.	Inoperable Pressure Sensor (S1)	IV	D	1. Ability to sense vent line blockage negated 2. "Over Pressure" warning capability negated 3. Fuel flow not verifiable 4. Diagnostics impeded
18.	Inoperable Fluid Level Sensor (S2-S10)	III	D	1. Loss of ullage control during refueling operations 2. Fuel level data accuracy diminished 3. Loss of suction in transfer lines 4. Introduction of air into supply lines 5. Main propulsion unit and APS shut-down 6. Diagnostics impeded
19.	Inoperable Temperature Sensor (S11)	III	D	1. Loss of fuel temperature control 2. Loss of heater control 3. Fuel temperature exceeding flash point 4. Sump content (water and sediment) freeze-up, with resultant tank and valve damage 5. Diagnostics impeded
20.	Inoperable Water/ Sediment Sensor (S12)	III	E	1. Loss of drain valve control 2. Loss of contaminate control 3. Diagnostics impeded
21.	Inoperable Water Sensor (S13)	III	D	1. Loss of fuel filtration/ separation 2. Loss of filter/separator drain valve control 3. Diagnostics impeded

Item	Description of Failure	Risk Assessment		Result/Hazard
		Cat.	Prob.	
22.	Inoperable Receptacle Sensor (S14)	II	D	1. Improper vent apportionment 2. System over-pressure during refueling 3. Incapable of SARS Refuel/ Defuel 4. Diagnostics impeded
23.	Inoperable Flow Sensor (S15)	IV	D	1. Flow detection negated 2. Diagnostics impeded

II. Operational Hazards

Normal operation of the FARV will expose it to small arms fire and similar combat related circumstances. Hazards associated with combat exposure are not addressed herein. The following "Operational Hazards Analysis" cites those hazards resulting from peace time use and field training exercises. The analysis addresses SARS Refueling/Defueling, manual refueling, robotic receipt of fuel from another FARV, fuel transport, and AFAS refueling. Though closely related, the analysis does not attempt to identify hazards associated with the storage and mechanical conveyance of the munitions and LP.

Operational Hazards Analysis

Item	Hazard Description	Risk Assessment		Effect on Personnel/ Equipment
		Cat.	Prob.	
1.	Improper, or lack of, vehicular bonding upon docking	I	D	Possible fuel or liquid propellant ignition in an explosion and fire. Severe injury, death and mission equipment loss can be expected.
2.	Improper positioning of SARS receptacle (curbside or road-side)	I	E	Possible vent gas flash-over or ignition. Possible fuel spillage to chassis interior. Severe injury, death and equipment loss can be expected.

Item	Hazard Description	Risk Assessment		Effect on Personnel/ Equipment
		Cat.	Prob.	
3.	Failure to connect and fully lock SARS nozzle	II	D	Terminated or impeded fuel flow. Fuel spillage and vent gas plume. Possible fuel and/or vapor ignition with probable severe personnel injury.
4.	Absence of hand-holds and non-slip deck surfaces	II	C	Possible severe injury and death can result from falls incurred while attempting to reach the Manual Fill Port. Fuel spills and exposure to raw fuel can result from dropping fuel container during fall. Mission interruption can be expected.
5.	Attempted docking beyond 10° vehicle attitude	II	D	Component damage to docking interface. Probable fuel spillage. Mission interruption can be expected.
6.	Failure of receptacle locking device	II	E	Possible vent gas escape via an unprotected port resulting in contaminant entry and possible vapor ignition with system fire and explosion. Severe injury and equipment damage can be expected.
7.	Open Manual Fill Port while moving	III	D	Possible contaminant entry to system. Mission interruption can result.
8.	Improper, or lack of, grounding during manual refueling of vehicles not equipped with SARS	I	D	Possible static discharge could ignite fuel vapors and result in fire and explosion. Severe injury, death and equipment loss can be expected.
9.	Failure of annunciator (MMCS)	III	C	Failure of alarm annunciation can result in system interrupt, mission interrupt, equipment loss, severe injury and death.

Item	Hazard Description	Risk Assessment		Effect on Personnel/ Equipment
		Cat.	Prob.	
10.	Maintenance access open or not secured	III	C	Probable reduction in fire containment capability. Possible loss of crew compartment NBC integrity. Personnel injury and illness could result from exposure to fuel vapors, excess heat and contaminants.
11.	Lack of warnings and labeling related to electrical shock hazards	II	C	Possible severe injury, death and equipment loss can result from static electricity discharge during refuel/defuel operations.

III. Maintenance and Repair Hazards

The hazards and difficulties encountered during maintenance and repair of the FARV Fuel System are minimized by adequate training. It is assumed, for the purpose of this analysis, that the FARV Fuel System is fully accessible. The munitions and fuses have been safely removed and stored. The LP has been drained, containerized, and removed from the immediate area, and that the residual vapors have been evacuated from the LP tanks. The vehicle is "powered down" and the fuel tanks have been drained and certified safe for workers - safe for hot work in preparation for component replacement. The maintenance area is adequately ventilated, illuminated, and the required tools are available for use by trained maintenance personnel.

The design of the vehicle, its compartmentalization, partitions and access panels permit access to, and removal of, all system components.

By definition, there is no direct personnel interface with the EEIM of the FARV Fuel System. Commands are issued by, and system status is monitored by, the MMCS. Therefore, no system controls are analyzed for hazard or HFE compatibility.

Maintenance Hazards Analysis

Item	Hazard Description	Risk Assessment		Effect on Personnel/ Equipment
		Cat.	Prob.	
1.	Residual fuel in line	III	C	Possible personnel exposure to raw fuel and vapors. Minor injury or illness can be expected.
2.	Failure to ventilate chassis	II	D	Possible personnel exposure to high concentrations of fuel vapors. Concentrations could reach unhealthful and explosive levels. Severe injury, illness and possible equipment damage can be expected.
3.	Generation of, and exposure to, open flame or spark	I	D	Probable severe personnel injury, death, and equipment loss from ignition of residual fuel and vapors.
4.	Lack of component identification and labeling	IV	D	Possible replacement of wrong component and continued malfunction of system segment or component.
5.	Application of AC current to DC circuitry	II	E	Possible loss of control circuitry or software/ firmware. Equipment loss and mission failure can be expected.
6.	Diagnostic failure - software/firmware	II	D	Possible mis-repair or replacement of functional component with probable continuing system malfunction.
7.	Contact with hot fuel or equipment surface	III	D	Probable minor injury or illness can be expected.

APPENDIX D

DESIGN DATA - WEIGHTS AND VOLUMETRIC DISPLACEMENT OF COMPONENTS (COTS/NDI)

The design data furnished is representative of that materiel currently available as COTS and NDI. The choice of components was predicated on compliance with the performance requirements and cost, not limited by weight and size (see paragraph 4.1.1).

The data provides further credence to the necessity to design and manufacture components for the specific use of the FARV and AFAS. The information does not represent components which may be in existence in the DOD inventory but that are protected by layers of "classification", or "need-to-know" regulations. Components, manufactured from light weight alloys, specifically designed for the application, would reduce the weight and volume of the components.

DESIGN DATA - FARV FUEL SYSTEM

Ref Para	Nomenclature	Weight Kg (lbs)	Width mm (in.)	Length mm (in.)	Height mm (in.)	Volume cu cm (cu in.)	Qty
4.2.1.1	Manual Fill Port		127 dia. (5.00)	228.6 (9.00)	N/A	2884.6 (176)	1
4.2.1.2	SARS Receptacle		254 dia. (10.00)	177.8 (7.00)	N/A	9014.5 (550)	2
4.2.1.3	Auto-Receiver	TBD	TBD	TBD	TBD	TBD	1
4.2.3.1	Down Tank	146.1 (322)	558.8 (22.00)	2082.8 (82)	558.8 (22.00)	650486 (39688)	1
4.2.3.2	Saddle Tank (LH/RH)	154.2 (340)	203.2 (8.00)	2895.6 (114)	711.2 (28.00)	418535 (25536)	2
4.2.4.1	Vent Diverter Valve	40 (18.1)	177.8 (7.00)	203.2 (8.00)	355.6 (14)	12849.8 (784)	1
4.2.4.2	Vent Selector Valve	40 (18.1)	177.8 (7.00)	203.2 (8.00)	355.6 (14)	12849.8 (784)	1
4.2.4.3	Shut-Off Valve Tank Supply	40 (18.1)	6 (152.4)	7 (177.8)	14 (355.6)	588 (9637.3)	3
4.2.4.4	Tank Drain Valve	9.1 (20)	101.6 (4.00)	101.6 (4.00)	279.4 (11.00)	2884.6 (176)	3
4.2.4.5	Refuel/Defuel Valve	18.1 (40)	177.8 (7.00)	203.2 (8.00)	355.6 (14)	12849.8 (784)	1
4.3.1.1	VFM Pump	15.9 (35)	101.6 (4.00)	279.4 (11.00)	177.8 (7.00)	5048.1 (308)	1

DESIGN DATA - FARV FUEL SYSTEM

Ref Para	Nomenclature	Weight Kg (lbs)	Width mm (in.)	Length mm (in.)	Height mm (in.)	Volume cu cm (cu in.)	Qty
4.3.2.1	VFM Filter/ Separator	4.54 (10)	177.8 dia. (7.00)	N/A	584.2 (23.00)	14505.2 (885)	1
4.3.2.2	Filter/Separator Drain Valve	1.36 (3)	50.8 (2.00)	76.2 (3.00)	101.6 (4.00)	393.4 (24)	1
4.3.3.1	Tank Selector Valve, Supply	11.3 (25)	101.6 (4.00)	101.6 (4.00)	279.4 (11.00)	2884.6 (17)	1
4.3.3.2	Tank Selector Valve, Return	11.3 (25)	101.6 (4.00)	101.6 (4.00)	279.4 (11.00)	2884.6 (17)	1
4.3.3.3	Directional Valve, Supply	11.3 (25)	101.6 (4.00)	101.6 (4.00)	279.4 (11.00)	2884.6 (17)	1
4.3.3.4	Directional Valve, Return	11.3 (25)	101.6 (4.00)	101.6 (4.00)	279.4 (11.00)	2884.6 (17)	1
4.4.1.1	FTM Pump	27.22 (60)	304.8 (12.00)	685.8 (27.00)	381 (15.00)	79655.4 (4860)	1
4.4.2.1	FTM Filter/ Separator	61.24 (135)	457.2 dia. (18.00)	N/A	787.4 (31.00)	129284 (7888)	1
4.4.3.1	Tank Transfer Valve	18.1 (40)	152.4 (6.00)	177.8 (7.00)	355.6 (14.00)	9637.3 (588)	3
4.4.3.2	Pump Inlet Valve	18.1 (40)	152.4 (6.00)	177.8 (7.00)	355.6 (14.00)	9637.3 (588)	1
4.4.3.3	Pump Outlet Valve	18.1 (40)	152.4 (6.00)	177.8 (7.00)	355.6 (14.00)	9637.3 (588)	1

DESIGN DATA - FARV FUEL SYSTEM

Ref Para	Nomenclature	Weight Kg (in.)	Width mm (in.)	Length mm (in.)	Height mm (in.)	Volume cu cm (cu in.)	Qty
4.4.3.4	Fuel Trans-ship Valve	18.1 (40)	152.4 (6.00)	177.8 (7.00)	355.6 (14.00)	9637.3 (588)	1
4.4.3.5	Manual Globe Valve	9.1 (20)	127 (5.00)	152.4 (6.00)	279.4 (11.00)	5408.7 (330)	1
	SUBTOTAL	863.7 (1,904)				1,888,242.7 (115,207)	

Ref Para	Nomenclature	Weight Kg (in.)	Width mm (in.)	Length mm (in.)	Height mm (in.)	Volume cu cm (cu in.)	Qty
4.5.1.1	Liquid Level Sensor (Hi/Lo) Controller	.91 (2)	127 (5.00)	101.6 (4.00)	63.5 (2.5)	819.5 (50)	6
4.5.1.1	Liquid Level Sensor (Hi/Lo) Fiber Optic Switch	.45 (1)	17.5 dia. (.69)	44.4 (1.75)	N/A	11.5 (.7)	6
4.5.1.2	Liquid Level Sensor (Intermediate) Controller	.91 (2)	127 (5.00)	101.6 (4.00)	63.5 (2.5)	819.5 (50)	21
4.5.1.2	Liquid Level Sensor (Intermediate) Fiber Optic Switch	.45 (1)	17.5 dia. (.69)	44.4 (1.75)	N/A	11.5 (.7)	21

DESIGN DATA - FARV FUEL SYSTEM

Ref Para	Nomenclature	Weight Kg (lbs)	Width mm (in.)	Length mm (in.)	Height mm (in.)	Volume cu cm (cu in.)	Qty
4.5.1.3	Water/Sediment Sensor	.91 (2)	50.8 dia. (2.00)	254 (10)	N/A	516.3 (31.5)	3
4.5.1.4	Pressure Sensor, Liquid	.23 (.5)	44.4 dia. (1.75)	66.6 (2.62)	N/A	103.3 (6.3)	3
4.5.1.5	Temp Sensor Transmitter	.23 (.5)	82.6 (3.25)	101.6 (4.00)	31.8 (1.25)	266.3 (16.25)	3
4.5.1.5	Temp Sensor Sensor Assembly	1.13 (2.5)	88.6 dia. (3.25)	288.6 (10.5)	N/A	1425.9 (87)	3
4.5.1.6	Receptacle Sensor	.91 (2)	44.4 (1.75)	44.4 (1.75)	101.6 (4.00)	200.8 (12.25)	4
4.5.1.7	Pressure Sensor, Vapor	.23 (.5)	44.4 dia. (1.75)	66.6 (2.62)	N/A	103.3 (6.3)	3
4.5.1.8	Flow Sensor, Liquid	1.82 (4)	101.6 (4.00)	101.6 (4.00)	152.4 (6.00)	1573.4 (96)	1
4.5.1.9	Fuel/Vapor Sensor						1
4.5.1.10	Valve Position Sensor	N/A	N/A	N/A	N/A	N/A	17
4.5.1.11	Attitude Sensor	1.36 (3)	127 (5.00)	101.6 (4.00)	50.8 (2.00)	655.6 (40)	1
	SUBTOTAL	48.92 (108)				31,800.7 (1,940.25)	

DESIGN DATA - FARV FUEL SYSTEM

Ref Para	Nomenclature	Weight Kg (lbs)	Width mm (in.)	Length mm (in.)	Height mm (in.)	Volume cu cm (cu in.)	Qty
NA	2 in. Tubing, Manifolds, Misc.	61.9 (136.5)	50.8 dia. (2.00)	24463.3 (963.12)	N/A	49591 (3025.7)	
NA	3/4 in. Tubing, Hose, Misc	23.5 (51.8)	19.1 dia. (.750)	19583.4 (771.8)	N/A	5587.4 (340.9)	
	TOTAL	995.94 (2,196.2)				1,972,992.8 (12,144.8)	